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THE TECHNOLOGY QUARTERLY

AND PROCEEDINGS OF THE SOCIETY OF ARTS

VOLUME XIX

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BOSTON
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
1906

The Massachusetts Institute of Technology held its first meeting on April 8, 1862. By the act of incorporation, which was accepted at this meeting, the Society of Arts was created as a part of the Institute coördinate with the School of Industrial Science.

The objects of the Society are to awaken and maintain an active interest in the sciences and their practical applications, and to aid generally in their advancement in connection with the arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May.

The Society discontinued the publication of the *Abstracts of Proceedings* in 1891, and since then has published its proceedings and the principal papers read at its meetings in the *Technology Quarterly*. The present volume contains the proceedings from October, 1905, to May, 1906, inclusive.

The *Quarterly* contains, also, the results of scientific investigations carried on at the Institute, and other papers of interest to its graduates and friends.

Neither the Massachusetts Institute of Technology nor the Society of Arts assumes any responsibility for the opinions or statements in the papers.

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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS

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PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-FOURTH YEAR, 1905-1906

Boston, October 12, 1905.

The 612th regular meeting of the Society of Arts was held at the Institute in Room 22, Walker Building, on Thursday evening, October 12, 1905, at eight o'clock. President Henry S. Pritchett presided. Seventy-eight persons were present. The report of the previous meeting was read and approved. After brief remarks by the President, in which he spoke of the early history of the Society, Professor Charles-Edward A. Winslow, Biologist-in-Charge of the Sanitary Research Station and Sewage Experiment Laboratory, spoke of the "Disposal of City Sewage."[1] Mr. Winslow outlined the history of sewage disposal, not only in America, but also in England and Germany, and described the principal methods which have been developed and the conditions under which each of these is most suitable for use. He pointed out that the geological and climatic conditions in different parts of the world made it impossible to employ a single method which

[1] Technology Quarterly, 18, pp. 317–332.

would give good results in all cases. He described the various methods now in use for the disposal and purification of sewage, mentioning Discharge into Large Bodies of Water, Broad Irrigation, Slow Sand Filtration, Contact Filters, Septic Tanks, and Trickling Filters, and mentioned the work now being done at the Experiment Station of the Institute. The lecture was illustrated by lantern slides showing the construction and operation of plants in which these different methods are employed. The President expressed the thanks of the Society to the speaker, and the Society adjourned.

Boston, October 26, 1905.

The 613th regular meeting of the Society of Arts was held at the Institute, Room 22, Walker Building, on Thursday evening, October 26, at eight o'clock. Professor William T. Sedgwick presided, and about 240 persons were present.

Mr. William Lyman Underwood addressed the Society on "The Brown-Tail and Gypsy Moths, Their Life Histories and Some Suggestions for Their Suppression." Mr. Underwood described the way in which these insect pests were introduced into this country from the continent of Europe, and in a very clear and interesting way traced out the life histories of each of these organisms from the egg through the larval and pupal stages to the mature moth, and back to the egg. He showed by a magnificent series of colored slides the natural appearance of each of these organisms in all their stages, and pointed out the characteristics by which each could be recognized. He further described the ravages wrought by these insects, and showed the effect of spraying as a means of preserving vegetation from their action. Mr. Underwood expressed the opinion that the moths could never be completely eradicated, but felt that much could be done to suppress them if each property owner would eliminate them from his own place. He spoke of the efficacy of arsenate of lead as a spray and of "tanglefoot" as a means of entrapping the insects on the trunks of trees and around electric lights. After some discussion, participated in by P. P. Field, Dr. Robert P. Bigelow, Dr. H. P. Talbot, and others, the meeting adjourned.

Boston, November 9, 1905.

The 614th regular meeting of the Society of Arts was held at the Walker Building, at the Institute, on Thursday evening, November 9, at eight o'clock. Colonel E. H. Hewins presided. One hundred and twenty-eight persons were present. The minutes of the previous meeting were read and approved. The following gentlemen were elected to Associate Membership in the Society: Mr. Earle B. Phelps, Sewage Experiment Station, Boston; Mr. Herbert O. Keay, Boston and Maine Railroad, Boston; Mr. Albert E. Kimberley, Testing Station, Columbus, Ohio. The presiding officer then introduced Mr. Henry R. Gilson, who addressed the Society on "Submarine Signaling."[1] He described the different systems of signaling through air, both by visual and sound signals, and then gave a detailed account of the new method by which the ringing of a bell is transmitted through water to a specially constructed receiver, or "ear." The applicability of this method to submarine or torpedo boats, warships, and cruisers, as well as to other kinds of vessels, was described, as were also the mechanisms involved. The advantage of this system over visual and sound signals in the air was demonstrated. The lecture was illustrated by means of lantern slides.

At the close of the lecture discussion on the subject was participated in by Professor Stone, of Kansas University, and Mr. Horace B. Gale, of Boston.

A vote of thanks was extended to the speaker, and the Society adjourned.

Boston, November 23, 1905.

The 615th regular meeting of the Society of Arts was held at the Institute, Room 22, Walker Building, on Thursday evening, November 23, 1905, at eight o'clock. Professor William T. Sedgwick presided. Two hundred and thirty-eight persons were present.

The following gentlemen were elected to Associate Membership in the Society: Mr. S. A. Breed, Boston; Mr. Kenneth Lockett, Chicago, Illinois; Mr. Julius B. Waterbury, Boston; Mr. Horace B. Gale, Boston; Mr. Henry D. Jackson, Boston; Mr. Henry R. Gilson, Boston.

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[1] Technology Quarterly, 18, pp. 365–381.

The chairman then introduced Professor Percival Lowell, Director of the Astronomical Observatory at Flagstaff, Arizona, who addressed the Society on the subject of "Recent Researches on the Canals of Mars." The lecture was illustrated by a large number of interesting maps and diagrams showing the most important of the so-called canals. The relation of these to vegetation was suggested and theories advanced why vegetation should make its first appearance at the poles and gradually work its way towards the equator. Some interesting slides showing views of the observatory and of the telescopes were also shown.

After a short discussion the Society adjourned.

Boston, December 14, 1905.

The 616th regular meeting of the Society of Arts was held at the Institute, Room 22, Walker Building, on Thursday evening, December 14, 1905, at eight o'clock. Mr. George W. Blodgett, chairman of the Executive Committee, presided. One hundred and forty-eight persons were present. The records of the previous meeting were read and approved. Messrs. E. P. Turner and H. C. Turner were elected to Associate Membership in the Society.

The chairman then introduced Professor Robert H. Richards, who addressed the Society on "The Treatment of the Black Sands of the Pacific Coast by the United States Geological Survey."

The speaker described some of the methods used to obtain the sands subjected to treatment, especially hydraulicking and dredging. He also showed the methods of classifying and the results obtained in the experiments conducted at Portland, Oregon, during the exposition, pointing out that the most valuable products obtained were those not sought at the outset of the investigation. The paper was illustrated by lantern slides.

The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

Boston, January 11, 1906.

The 617th regular meeting of the Society of Arts was held at the Institute, Room 22, Walker Building, on Thursday evening, Janu-

ary 11, at eight o'clock. Professor W. H. Niles presided. Thirty-eight persons were present. The minutes of the previous meeting were read and approved.

The chairman then presented Professor Alexander F. Chamberlain, of Clark University, who addressed the Society on the subject of "The American Indian Folklore."

The speaker was tendered the thanks of the Society, and the meeting adjourned.

BOSTON, January 25, 1906.

The 618th regular meeting of the SOCIETY OF ARTS was held at the Institute, Room 22, Walker Building, on Thursday evening, January 25, 1906, at eight o'clock. Seventy-three persons were present. Professor Robert H. Richards presided. The minutes of the previous meeting were read and approved. Mr. W. W. DeBerard was elected an Associate Member of the Society.

Mr. Howard W. DuBois, Mining Engineer, of Philadelphia, Pennsylvania, was then presented by the chairman, and addressed the Society on "Hydraulic Mining in British Columbia and Alaska." Mr. DuBois explained the methods employed in hydraulic mining and the conditions under which they are applicable, and showed by illustrations the great economy of this method as it is used in British Columbia and Alaska.

He also showed a very large number of beautifully colored slides, giving a very clear picture of the scenery in Alaska and of the difficulties in approaching the gold fields.

The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

BOSTON, February 8, 1906.

The 619th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, Massachusetts Institute of Technology, on Thursday evening, February 8, 1906, at eight o'clock. Attendance, forty. President Henry S. Pritchett presided. The minutes of the previous meeting were read and approved.

There being no routine business, the President presented the speaker of the evening, Professor Douglas W. Johnson, who addressed the Society on the subject, "Causes and Effects of River Capture."

Dr. Johnson explained what is meant by the term "capture," describing it as a sort of invasion of the watershed of a stream by the tributaries of another system in which the erosive action is going on more rapidly, and whose sources are therefore gradually becoming more remote. The different ways in which this action may take place were shown in a very clear manner, and specific cases in which the capture has been effected were well shown by means of maps and diagrams. The effects of such captures were described in detail, as well as the methods of proving that such changes have taken place.

The lecture was illustrated by excellent stereopticon slides demonstrating salient points.

The President expressed the thanks of the Society to the speaker and declared the meeting adjourned.

S. C. Prescott, *Secretary.*

MODERN LANGUAGE TEACHING, WITH SPECIAL REFERENCE TO PRONUNCIATION AND CONVERSATION

By JOHN BIGELOW, Jr.

The principal uses of foreign languages at college and in a graduate's after life may be stated in order of importance as follows: —

1. Reading.
2. Writing.
3. Speaking.
4. Culture.

It is a common fault of our schools and colleges to place the last of these first, to neglect language for literature, to run to literature, thus entailing long lessons in reading and precluding the proper discussion of their diction and syntax. While the French language is being studied there is no time for discussing the motives and character of the *Cid* or of Tartuffe, or for the explanation of the obsolete words and phrases of Molière, Corneille, and Racine. One should not in this period go back of Balzac for examples of French prose.

The common practice of reading from a French or German reader in English is good mental discipline, and good exercise in the use of English, but is not good training in the use or comprehension of French or German. It defeats what should be the main object of the reading — making the pupil think in a foreign language. If a teacher could look into a pupil's head and see as he reads just what he understands, a recitation in French reading would consist mainly in reading on the part of the pupil, and in observing the working of the pupil's mind, or mind-reading, on the part of the teacher. As it is, the teacher's only way of finding out what the pupil knows is to submit him to a test. But there are ways of doing this without making him speak English. Let the teacher commence by asking the whole class, say in French, what difficulties, if any, they found in the lesson and were not able to overcome. All answers to this question should have to be given in or rendered into French; for instance, "Monsieur, je ne comprends pas

ce que veut dire à la page trente-six, ligne quatorze, le mot 'enseignement'"; or, "S'il vous plaît, expliquez-moi au paragraphe douze, ligne trois, la phrase 'c'est-à-dire.'" The teacher may then proceed to call up in turn the pupils that are to read, and question them in French upon the lesson, or the more difficult parts of it, requiring them as much as possible to answer in French. It will rarely be advisable to go over the whole lesson in this way. This I would call the *question* method.

As another form of test the pupil may be given a number of lines of the reader to translate in writing into English, and be required then to translate his English back into French without looking at the French text. This I would call the *translation* method. As another such exercise, the teacher may read a few lines of the reader in French and have the pupils write it in English and then translate their English into French. This may be called the *dictation* method.

The first, or question method, is the best for small and rather advanced classes. It is the most difficult for the teacher as well as for the pupils. It has the great advantage that it does not involve any use of English, that is, when strictly carried out. An English word will perhaps have to be used now and then. But before resorting to English the teacher should exhaust his ability to make himself understood in French. He should repeat what he says in various forms, explaining by synonyms, signs, gestures, etc., what he judges to be the principal difficulties. A verb which is not understood may sometimes be made clear by a statement in French of the person, tense, and infinitive. If all this fails, he would do well to write what he wants to communicate on the blackboard in French. What is not understood when spoken is often understood when written. If he decides to use English, he should habitually do so in writing rather than orally. If, finally, he does use English orally, he should immediately repeat himself in French, so that the last impression made shall be of French.

The translation and dictation methods both require the writing of English, but do not involve any talking of it. The dictation method has the peculiar advantage that it does not require the pupil to use his book. It is thus independent of notes which he may have made in it, or of the length of time that a reader is kept in use. In the translation method such notes may assist a pupil in writing his English, but as he has to write his French without a text he can have no such assistance in that, the principal, part of the exercise. Moreover, the translation method may be practiced without books, the instructor fur-

nishing the pupils extracts therefrom on loose sheets kept by himself for that purpose. Each of these methods may be abridged by omitting the translation from English into French, or reduced to simple translation into English.

Of the three methods the easiest is that of translation. If taken successively the translation method (whole or abridged) should come first, the dictation method (whole or abridged) next, and the question method last. But they may all be used from the beginning, in alternation with one another. The oral translation of French or German into English should be totally discarded.

Whatever method is employed, the written or spoken exercises should be followed by reading of the French text in French. The usual practice is to read in French first and in English afterwards. The French is often not read at all. When it is read, two, three, or four lines may be read in English to every one that is read in French. This is all wrong. The translation should precede the reading in French, and this reading should be at least as prominent a feature of the exercise as the translation. I consider it a good practice to give the first half of the hour to translation and the second half to reading, and to have the whole class read aloud every passage that an individual pupil is to read, the class reading it before the pupil is designated. Should this be impracticable for lack of time, the whole class should read at least one passage.

In technical or scientific reading the pupils should understand the technology or science that they are reading about. In this, as in other reading, the pupils should know, not only the words that they see and use, but also the things that the words stand for. There are two scientific French Readers that seem to be widely used in the schools and colleges of the United States, each of which gives a description of a steam engine without a drawing, plate, diagram, or graphic illustration of any sort. The average pupil knows practically nothing about a steam engine when he commences to read one of these descriptions, and little if anything when he gets through. The teacher, if he is able to, may make a drawing for his class, and point out the parts as their names are reached. But the instruction is more apt to be confined to words. The pupil may learn that there is in a steam engine a something or other that Americans call a *sliding valve* and that Frenchmen call a *tiroir,* but in what part of an engine a sliding valve functions, what it looks like, what it does, what the word *tiroir* stands for, these are points on which he has at the best but a faint and inadequate idea.

Notices posted on a bulletin board should, as a rule, be in a foreign language. That a notice may possibly not be understood, say in French, is not in itself sufficient reason for putting it in English. Is it necessary that it be understood at all? Many of the notices posted on school and college bulletin boards are of no great importance, or if they are, should be understood in a foreign language. A notice, for instance, about courses in sight reading does not concern any student who cannot read it in the foreign language. Whenever and for whomsoever notices may be posted in English, they should, if practicable, be accompanied by a translation.

As a rule, the texts on blank forms, printed slips, charts, drawings, etc., used in the classrooms should be in the language studied. As illustrations I present the following forms which I have found useful in my own sections. The spaces occupied by the words in italics are left blank. Words not wanted in the instructions are struck out.

LEÇON *38*

Traduisez en anglais et retraduisez en français sans regarder le texte français :

Tout en se hâtant de faire les commissions, Julien regardait le pays. . . .

LEÇON *12*

Écrivez en français :
anglais :

Yes, we visit all the members of our family. . . .

LEÇON *8*

Indiquez de quelle préposition on doit faire précéder les infinitifs qui dépendent des verbes et des expressions suivants : *forcer, se mettre, vouloir, être à même* .....

LEÇON *13*

Écrivez les temps primitifs, l'impératif (s'il y en a), et la $\begin{matrix}\text{première}\\\text{deuxième}\\\text{troisième}\end{matrix}$ personne du $\begin{matrix}\text{singulier}\\\text{pluriel}\end{matrix}$ de tous les autres temps, des verbes suivants :

A la forme affirmative.	A la forme négative.	A la forme interrogative.	A la forme négat-interrog.
Forcer	*S'évanouir*	*Vendre*	*Valoir*
. . . . .	*Punir*	. . . . .	*Se promener*
. . . . .	. . . . .	. . . . .	. . . . .

Pupils should be required in writing out verbs to give the moods and tenses in the language studied. They should be so given in all text-books.

In the translation of measures foreign terms should be converted into American: metres into yards; kilometres, leagues, and German miles into statute miles; kilograms into pounds; marks, francs, and centimes into dollars and cents; degrees Centigrade into degrees Fahrenheit, and *vice versa*.

In the study of a language the one object of the pupil should be to master it, and of the teacher to help him do so. Mental discipline should be considered only as an incident which may be trusted to take care of itself, provided that thoroughness be insisted upon. Lessons and exercises should not be made difficult with a view merely to training the mind. The disciplining of the mental faculties, considered as a separate function of education, may safely and fairly be left to courses which have not the peculiar difficulties of language teaching to contend with.

The acme of linguistic attainment is to speak and write a foreign language like a native. Such perfection is hardly attainable without a residence of years in the home or mother country of the language. Moreover, it is not, generally speaking, worth the time or labor that it costs. Nobody but a spy, or possibly an actor, has need or occasion to pass himself off for a foreigner. On the other hand, it is not enough

for conversation with a foreigner to be able to speak so as to be understood. One must have a pronunciation that will not shock his ears. The object of instruction in oral or spoken French or German should be to speak that language intelligibly and with a tolerable accent.

Teachers talk too much English and not enough of the language that they are teaching. Many of them are foreigners, speaking English with a foreign accent. Much of the time and energy that might be devoted to training the ear to understand a foreign language is worse than wasted in accustoming it to bad English.

The teacher should seize every opportunity of conversing with his pupils. For a considerable time the conversation will be largely one-sided; that is, the foreign language will be nearly all furnished by the teacher. The progress made will depend upon the time available for such exercise and the size of the class or section. But even when the pupils answer in English, something is being done by accustoming their ears to the foreign language. It is a great mistake to suppose that pronunciation must be acquired exclusively by practice therein; that nothing else contributes to its acquisition. Not many years ago the director of modern languages in the Boston schools, addressing a meeting of classical and high school teachers, made use of the following language: —

Now let us suppose that a class of twenty-five pupils, neglecting all else, spends its whole time in "conversation"; let us say that each recitation period consists of fifty minutes, and that the class recites three times a week; let us suppose, also, for the sake of the argument, that the instructor talks only half of the time. What is the result? If the hours are equitably divided, every pupil speaks for three minutes a week, or two hours yearly, or a quarter of a day during his entire public school career. When we reflect that it takes us, with fully an hour's exercise *per diem*, ten or fifteen years to master our native tongue, we can perhaps estimate the amount of skill that is to be produced by six hours' practice scattered over a term of three years. It will then be unnecessary to discuss the question whether or not the ability to speak French or German is a desirable and proper object for a public school course.

The director leaves out of account entirely the speaking done by the instructor and by pupils not addressed by him. He implies that a pupil gets nothing from the speaking done by anybody but himself. I wonder what he thinks of the practice of going abroad to learn to speak a foreign language? If one learns nothing except by speaking oneself, one might as well stay at home and do it there. The speaking done by the teacher is not only helpful, but an essential part of

the instruction in conversation. The speaking of fellow-pupils is also helpful.

In the next place, the director assumes that not more than one pupil can practice speaking at a time. I have found it a difficult thing in my own sections to prevent (when I want to) more than one pupil speaking at a time. It is probably a common experience with teachers when they question a pupil to get two or three or more answers from as many pupils. Speaking by more than one pupil at a time is, in fact, unavoidable, and may be advantageously encouraged and regulated. A whole class or section may be practiced in repeating passages of French together. Occasional errors will pass unnoticed; certain pupils will perhaps lag or not speak at all. But exercises of this sort will be far from wasted, and practiced in moderation, especially during the early stages of instruction, will be found effective, time-saving, and altogether satisfactory.

"It takes us," he says, "with fully an hour's exercise *per diem* ten or fifteen years to master our native tongue." It is not proposed to make American youth "master" any foreign tongue. As to this imaginary, fictitious, daily period of one hour which we are said to devote from the time we are born until we are fifteen years old to exercises in speaking English, at least half of it comes before our brains are fully grown. A large part of our work consists in unlearning what we have learned from bad example. What relation is there between such a period of exercise and a period of equal length devoted to modern language instruction between the ages, say, of fifteen and eighteen? The two values are essentially different. They cannot be expressed or conceived in terms of each other. They are absolutely incommensurate.

Nor is any consideration given to the periods of preparation. Do not three hours of recitation carry with them three hours, more or less, of study or practice at home? If a pupil will only practice by himself reading aloud in French and studying rules of pronunciation he may do a good deal towards the perfection of his accent. It would seem, indeed, but in a sense as different as can be from that of the director's language, to be "unnecessary to discuss the question whether or not the ability to speak French or German is a desirable and proper object for a public school course."

Conversation, which at many of our colleges is a course by itself, should be an essential part of every course of instruction in language, and should commence at the first lesson.

It is a common and lamentable error on the part of teachers to underestimate the capacity of their pupils for conversation. Instead of being ahead of them and leading them on they are too often barely abreast of them or behind them. Nothing is more tiresome or discouraging to a class.

It may be regarded as an axiom in the minds of our teachers and professors that the study of foreign languages should be taken up at an early age; President Eliot says not later than the tenth or eleventh year. But unless pronunciation be taught, what greater mistake could there be than such a practice? As foreign languages are commonly taught in our schools and colleges today, the study of them may be pursued to better advantage between the ages of eighteen and twenty than it can at the age of ten or eleven.

Familiarity with the sound of a language is not only a preparation for speaking it, but a condition to the appreciation of its literature. There seems to be a common disposition to consider spoken language as a sort of extract of written language. It would be far more rational to consider written language as a condensation, a precipitation, of spoken language. The word *language* comes from the Latin word for tongue. It is essentially a form or ultimation of speech. There are two classes of extremists — one utilitarian, the other literary — who want to learn to read without learning to pronounce, to get the sense of a language without its sound. Imagine a man in the lumber business saying to his forester, with a wave of the hand: "I want you to raise trees on this land, but I don't care anything about leaves and branches. Leave all that out; just raise trunks." As the quickening essence of the sun pours through the leaves into the sap and fiber of a tree, so the genius of a people flows from their mouths as a stream of life into the grammar and vocabulary of a language. Reading, the utterance or silent apprehension of writing, is but an echoing of speech. People who profess to teach French or German without teaching to speak it may be teachers of French or German grammar or vocabulary, but not of the French or German language.

Pupils take more interest in a language as living than they take in it as dead. Parents wish their children taught the pronunciation of the languages that they study. Members of faculties, corporations, and similar bodies, seem generally to disbelieve in language without speech. It is almost solely among teachers and professors of languages that one finds apologists for the obnoxious pedagogy by which so many of them are producing deaf and dumb virtuosos in foreign literature. The neg-

lect of conversation in the instruction and study of foreign languages accounts in a measure for the tendency of instructors to rate students in this subject by hours or years of work done rather than by proficiency attained, and for the disposition of students to look upon the subject, not as an accomplishment or a talent that shall contribute to their happiness and usefulness in after life, but as a "grind," to be worked off as a condition to advancement in some school or college curriculum. Men come to me from our foremost universities and ask, almost demand, that they be excused from the study of French because of the number of years that they have pursued it, exhibiting ofttimes a list of the French books that they have read. I remark, "Alors vous parlez français, n'est-ce pas?" The usual reply is a look of surprise mingled with indignation or amusement, according as the question is taken seriously or as a joke.

Much of what is said by a teacher to his pupils, habitually in English, may just as well be said in a foreign language. It takes practically no longer to say, "Allez au tableau noir," than it does to say, "Go to the blackboard"; to say, "Asseyez-vous," than to say, "Sit down," or "Take your seat"; to say, "Ouvrez vos livres à la page vingt-cinq," than to say, "Open your books at page twenty-five"; to say, "Y a-t-il quelque chose dans la leçon que vous ne comprenez pas?" than to say, "Is there anything in the lesson that you do not understand?" These phrases would have to be explained perhaps once or twice, but being used over and over again, they would soon become familiar to the pupils. These and other locutions too numerous to mention or illustrate, used by every teacher as commonly as these, would become fixed in the average pupil's memory, and serve as nuclei for other sentences, as the beginning of a practical vocabulary and standard of pronunciation.

The strictly useful vocabulary of the pupils should be developed, not only by asking questions and requiring them to answer in French, by making conversation with them, but also and particularly by requiring them to put into French questions which they voluntarily address to the teacher in English — questions, for instance, as to the meaning of passages in the lesson, as to marks given them, as to books or other articles lost or found, etc. The lessons should habitually be given out in French, whether orally or in writing.

When a pupil is called upon to spell a French word aloud he should be required to spell it in French. A large proportion of our students of advanced French do not know the French alphabet. All parsing or

analyzing of sentences should also be done in French. In dictating in French the punctuation marks should be given in French. These and the parts of speech should be taught with the alphabet or the elements of pronunciation. While a teacher is correcting an exercise in French at the blackboard, he should read it aloud in that language. The teachers in their intercourse with one another, especially in the presence and hearing of pupils, should talk one of the languages taught. These are but instances of ways in which pupils may be indirectly and unconsciously impressed with the forms and sounds of a foreign language.

Pronunciation being recognized by the governing body of a school or college as an essential part of a language, the next thing is to bring the fact home to the pupils. The instructors should keep separate marks for pronunciation. The general or record mark should be the mean between the marks for *pronunciation* and for *grammar*, etc. For grading in pronunciation I venture to suggest the following scale based on the one in general use at the Institute of Technology.[1] The term "audible" means that can be heard and recognized as the language used at a distance of about 20 feet, and the term "tolerable," that can be listened to without pain by one who knows the language.

C	Audible, intelligible, tolerable, fluent, expressive	. . . .
P+	Audible, intelligible, tolerable, fluent	Inexpressive
P	Audible, intelligible, tolerable	Halting
L	Audible, intelligible	Intolerable
F	Audible	Unintelligible
FF	. . . .	Inaudible

Practice in the pronunciation of French is commonly begun on words and phrases. Better results may be obtained by beginning on the elementary sounds. A pupil in music is made to learn the notes before he begins to play bars. There has been, indeed, in recent years a school of reading that makes a child learn words before he is taught his alphabet. This method is responsible for much of the bad spelling of our school children and college students, and is now, I understand, generally discarded.

[1] C, passed with credit; P, passed; L, passed with low standing; F, failed to pass; FF, failed completely.

The following exercises are offered as an aid to teachers in conducting systematic drill in the pronunciation of French.

Vertical lines are placed as warning signals where changes of sound are to be made. The more important changes are signaled by double lines //.

First Exercise

The first exercise is divided into two paragraphs. The first consists of the alphabet. In the second paragraph the vowels are given, first by themselves, and then preceded by those consonants and combinations of consonants which offer some difficulty to English-speaking students.

The French *w*, which has two sounds (Eleventh Exercise), is here given its more common sound, or that of *v*. This exercise should be practiced along the horizontal lines and along the vertical lines or columns. Especial attention should be given to the *u* sound. In connection with the line *ra*, *re*, etc., it may be well to give a little practice in the Sixth Exercise, to be resumed and perfected when that exercise is regularly reached.

1. a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z.

2.

a	e	i	o	u	y	ou	oi	é	è	ê
ha	he	hi	ho	hu					
va	ve	vi	vo	vu					
wa	we	wi	wo	wu					
ga	ge	gi	go	gu					
ja	je	ji	jo	ju					
cha	che	chi	cho	chu					
qua	que	qui	quo	qu					
ra	re	ri	ro	ru					
ca	ce	ci	co	cu					
ça			ço	çu					

Second Exercise

The vowels are used in this exercise as parts of words. In some of these they sound as when alone; in others their sound is affected by other vowels, by adjacent consonants, by accents, or by diereses.

There are sounds that are easy to pronounce separately, but present considerable difficulty when occurring together. One may be able to pronounce the *u* and the *ou* sounds each by itself, but not the two united, as in the word *voulu*. For this reason special attention should be given to the portion of paragraph 6 following the word *août*.

1. la, ta, sa, mal/ Saar, Saale/ âne, âme// laid, mais, jamais// maïs, Sinaï// au, corbeau, chevaux/ Maure, Minotaure, restaure.

2. ne, me, se, te, le/ jeu, œufs, nœud, vœu/ œuf, seul, leur, veuve.

3. les, mes, et, parler, mener, blé/ cher, sel, sexe, peine, Seine, neige, terre, cette, nette, très, père, même// poêle, poêlier.

4. ni, si, fini/ Nîmes, fîmes, vive, assise.

5. dos, gros, mot, trône/ bonne, folle, molle, comme, personne// moi, soi, vois, foie/ noyé, noyau/ boîte, boiter, boiteux, coiffe, coiffer, coiffeur// Moïse, égoïste.

6. du, mur, fume, futur, suture/ luire, liure/ nuage, au fur et à mesure/ suer, tuer/ sueur, tueur// louer, nouer/ loueur, noueur// mou, fou, août// sus/ sous// au dessus/ au dessous// sur/ sourd// pur, pour// surtout/ pourvu// du tout/ voulu.

Third Exercise

The nasal sounds are given in paragraph 1 of this exercise by themselves, and in paragraph 2 in combination with other letters, forming words. They should be pronounced without any twang.

There are nasal sounds which like the sounds *u* and *ou* (Second Exercise) are particularly hard to render distinctly one immediately after the other. This exercise affords practice in doing this.

The non-nasal sound of *am*, *em*, *om*, *on*, and *en* is illustrated in paragraph 3.

1. an, en in on un oin

am, em aiñ om eun

ean ein

2. ban, flanc, dans, Jean, mangeant, vent, sens, serment, champ, jambe, temps, membre/ fin, malin, pain, bain, sein, frein/ bon, don, plomb, allons/ aucun, quelqu'un, jeun// foin, coin, point// menti, monta/ enfant// maintien, lointain// mentant/ montons/ menton, montant// trempons/ trompant// enfin, singeant/ en plein, pinçant/ enfantin, intendant, embonpoint.

3. flamme, femme, ardemment, patiemment/ comme, personne/ solennel.

Fourth Exercise

One may pronounce the several syllables of a word perfectly, and yet betray one's unfamiliarity with the word and with the language to which it belongs by misplacing the tonic accent. An Englishman or American says "ch*a*racter," placing the accent on the first syllable; a Frenchman says "caract*è*re," placing it on the last syllable; a German says "Kar*a*kter," placing it on the second or middle syllable. Thus in pronouncing practically one and the same word one is speaking English, French, or German, according to where one places the tonic accent. In French the tonic accent is invariably placed on the last syllable, words joined by a hyphen being intoned in this respect as a single word.

The tonic accent is ordinarily soft, gentle, often hardly perceptible, but it is always there. Let it be misplaced by only one syllable, and an ear used to the harmony of the French language will not fail to hear its false ring. Beginners in this exercise may unduly emphasize the last syllable or exaggerate the tonic accent, but this fault will correct itself.

In our country little attention is given by teachers of French to the tonic accent, even in those schools and colleges that pretend to teach pronunciation. A teacher who has a perfect pronunciation himself — he may be a Frenchman — will sit silent and unmoved while a pupil perpetrates such atrocities as *nátion, refúser, retoúrner, curiósité, révolútion, civilizátion.* The explanation of this seems to be that the teachers

do not know the law of tonic accentuation themselves. They have probably acquired their pronunciation without rule or law; in other words, by the natural method. They may perceive that the pronunciation of their pupils is wrong, but not know what is the matter with it or how to correct it. The head of the department of modern languages at one of our great institutions of learning directs that in the pronunciation of French there shall be no tonic accent; all syllables of the same word to be intoned alike. This is an anatomical impossibility. One cannot, except by a *tour de force*, pronounce words of more than two syllables without using a tonic accent. One who is not taught to place that accent right will almost inevitably place it wrong.

This exercise consists of three paragraphs. The first gives words of two syllables, followed by words of three or more formed by additions to the original words. The pronunciation of these words calls for a continual transference of the tonic accent to the last syllable.

The second paragraph consists of words which are spelled the same, or nearly the same, in English as in French. Great care or proficiency is required to avoid putting the emphasis where it belongs in English instead of where it belongs in French.

The last paragraph is formed of a few words and phrases containing hyphens.

1. dessin, dessiner; engage, engager, désengager; personne, personnel, impersonnel, impersonnellement; avant, avantage, désavantage, désavantageux, désavantageusement.

2. science, cordon, cordage, bureau, union, caractère, caractéristique, chocolat, carcasse, cardinal, bataillon, discipline, institut, université, technologie, culture, sépulture, Jules César, Napoléon Bonaparte.

3. peut-être, moi-même, viens-tu, va-t-en.

Fifth Exercise

This is an exercise in the liquid *l*.

1. ail eil euil ille ouille uille

aille eille euille

œil

2. bail, détail, faille, tressaille/ conseil, veille, vieille, abeille/ deuil, accueil, veuille, feuille/ fille/ fouille, mouille/ aiguille, juillet.

Sixth Exercise

The first paragraph of this exercise is devoted especially to the letter *r*. It is made up of words containing that letter and having the same form, or spelled alike, in French and in English. To bring out the difference between the English *r* and the French *r*, each of these words should be pronounced first in English and then in French.

The second and third paragraphs are devoted to the terminations *re* and *le*, respectively. English-speaking people are prone to pronounce these like the English terminations *er* and *le;* to sound the last syllable in the French words *sabre* and *sable* like the last syllable in the English words *saber* and *sable;* to render, for instance, *tout ensemble*, toot-on-sóme-bull. In the French word the *e* is heard, if at all, after the *r* or *l;* the sound of the *r* or *l* immediately follows that of the preceding consonant.

1. rat, rare, respect, ridicule, robe, rude, rupture, lucre, bronze, profit, quadrille, Rome, Paris, arc, retort.

2. battre, acre, fiacre, arbre, marbre/ cadre, sabre, âpre, âcre// neutre, feutre// lettre, guêtre, nègre, algèbre, maître// vitre, cidre// mordre, propre// foudre, coudre, poudre, pourpre// sucre, lustre, lugubre, huître// encre, gendre/ timbre, peindre, moindre/ contre, montre, monstre, Montmartre/ croître.

3. fable, sable, table, débâcle/ peuple, meuble/ règle, siècle, aigle, faible// cible, nuisible/ noble/ double// multiple, quintiple, muscle// semble, tremble// simple, épingle// comble, ongle, oncle/ humble, jungle// misérable, formidable, inévitable.

Seventh Exercise

The French have two sounds of *gn:* one liquid, as in the English word *singing;* one hard, as in the English word *ignorant*. Both are illustrated in this exercise.

Espagne, espagnol, baigna, saigna, seigneur, signifier, magnifique, magnolier, Boulogne, ivrogne, ignoble, ignorer, imprégner, ignorant// igné, stagnant, inexpugnable.

Eighth Exercise

This exercise is devoted to the pronunciation of the French *ti* followed by *a*, *o*, or *e*. It never has the *sh* sound of the English *ti* in such words as "attention." This should be impressed upon the pupils at the start.

partial, initial, insatiable, Dalmatie, facétie, démocratie, aristocratie, captieux, factieux, facétieux, ambitieux, initier, balbutier, partiel, essentiel, fiction, friction, faction, fraction, nation, national, association, Egyptiens// tiare, centiare, partie, sortie, septième, maintien, soutien.

Ninth Exercise

Words containing *h* mute.

l'habitude, l'hiver, l'hôtel, j'hésite/ bonheur, aujourd'hui, exhaler, inhabile, exhausser, exhaussement/ renhardir, enharnacher, déharnacher, cohorte, dehors, envahir/ la haine, les haines, je hais, la halte, le héros/ le chapeau d'Henri/ la mort de Henri IV.

Tenth Exercise

This exercise is devoted to the letter *w* at the beginning of certain words. In the words preceding the sign / it is sounded like *v*. In the words following that sign it is sounded as in English. The *i* is sounded as in French (First Exercise). The *ey* in *whiskey* is pronounced like *i*. The *h* is not sounded.

Wurtemberg, wagon, Watteau, Wagram/ whig, whist, whiskey, Wiclef, Windsor.

Before requiring the pupils to read these exercises the teacher should explain their general purpose, and go through them, reading and expounding each one. The exercises should be printed or drawn in the form of charts and kept in the classroom, so that when a pupil makes a serious mistake in pronunciation he may be referred to the appropriate exercise and practiced in it. The exercises should also be distributed to the class in convenient form for study at home, each French word accompanied by the corresponding English one. At the beginning of a course the exercises should be taken in succession, one or two at a time, for systematic drill.

I know that the teachers in our high schools have to prepare pupils for colleges, universities, and technical schools which do not require pronunciation for admission, and do require a certain knowledge of grammar and a considerable amount of reading. But I believe that, without trenching materially on the time given to these subjects, much may be done to improve the training in pronunciation. It should be impossible for a boy to escape from a year's course in French at any school with such a Franco-American travesty of a pronunciation as the average student brings to the Institute of Technology every year. It should not devolve upon instructors at the Institute to take graduates in school French through the French alphabet.

The art of teaching pronunciation has recently received from the mechanic arts a most valuable contribution, which has hardly begun to be appreciated. I refer to the *graphophone*, *languagephone*, or *talking machine*. No matter how small the class, a teacher cannot give it all the training in pronunciation that it is capable of receiving. Even assuming a single pupil to a teacher, one cannot suppose the pupil to have the teacher with him ready to pronounce for him whenever he may want to practice. A talking machine is always ready. This substitute for a teacher he can have practically whenever and wherever he wants it, and as long as he wants it. If he should try to get the equivalent of a machine in two or three teachers, he would experience the disadvantage of a change of models. No two persons pronounce exactly alike. Even the same person will vary his pronunciation. The talking machine is always the same, and all machines of the same make are alike. So one may have one invariable model in any single machine or any number of machines. This uniformity is an appreciable advantage in the early lessons. The peculiar merits of the talking machine are *indefatigability* and *invariability*.

I have been able to learn of but three types of the talking machine that are at present in use in teaching languages. These are the *Victor*, the *Columbia*, and the *Edison*. As an implement of language teaching, each of these machines is monopolized by a particular school or company: the Victor by the United States School of Languages, Main Office, 1127–1129 Walnut Street, Philadelphia; the Columbia by the International College of Languages, Main Office, Metropolitan Building, Sixteenth Street and Broadway, New York; the Edison by the International Correspondence Schools, Main Office, Scranton, Pennsylvania. Outfits, consisting of a machine with a supply of disks or cylinders,

books or manuals, and other appurtenances, are offered by these schools for sale at prices varying, as listed, from twenty to fifty dollars.

I expect the talking machine to prove useful in our schools and colleges in general, especially in helping along the few students in a class who may be considerably behind the rest or considerably in advance of it and ambitious or zealous in pronunciation. No matter how well one may be doing with a teacher alone or with a machine alone, one will do better with both, each more or less correcting the faults and supplementing the work of the other.

Not until proficiency in the first three uses of foreign languages — in reading, writing, and speaking — is attained or assured should the fourth use, or culture, be regarded as the chief purpose of instruction. The skipping or slurring of the alphabet, pronunciation, and composition to get at literature tends to accustom or reconcile a pupil to superficial study. The practice is an evil which school committees, college faculties, and other bodies having direction of education cannot be too prompt and vigorous in eradicating. They should repeal the requirement that applicants for admission to college shall have read from a hundred to three or four hundred pages of literature, and substitute for this requirement an examination in pronunciation corresponding to the laboratory examination in chemistry and physics.

Any one who holds the study of literature in esteem will deprecate the error of entering upon it with an inadequate command of language.

Literature should not be taken up as the sole or main subject of a course until the pupils are able to recite, follow lectures, take quizzes, etc., in French, German, or Spanish, as the case may be. A course of literature, forming part of a course in a foreign language, should be given only in that language. This stage of instruction cannot be reached at the Institute of Technology until about the end of the regular course or the middle of the advanced (optional) course. Instruction at this final stage should aim primarily at imparting an interest in and appreciation of foreign literature; and, secondarily, at developing, in conjunction with other studies, a taste and a certain fitness for every form of intellectual activity.

THE SCOPE OF APPLIED GEOLOGY, AND ITS PLACE IN THE TECHNICAL SCHOOL[1]

By DOUGLAS WILSON JOHNSON

An attempt to classify scientific work and workers may be a hazardous undertaking. At the same time it is occasionally necessary, for the sake of clearness, to make such an attempt. In order to present certain considerations relating to applied geology, it seems best to recognize three phases of scientific work, with corresponding groups of scientific investigators, students, and schools. The broad classification thus suggested appears to follow lines that are natural and easily recognized, although individual cases may present special difficulties.

Scientific research may be pursued primarily for the discovery of Nature's truths and a knowledge of the workings of her laws. There may be no attempt to obtain knowledge that will have a market value, and when finally attained the results of such research may be wholly worthless from the commercial point of view. To say that they have no *practical* value is not just, for they may possess a very high educational value, and the extension of our educational resources is a consideration of the greatest practical importance. A study of the successive stages in the development of a group of fossil shells, together with the bearing of that development on the theory of evolution, is an example of that phase of scientific research which is generally carried on without regard to the cash selling price of the knowledge obtained.

On the other hand, research may be conducted in a thoroughly scientific manner for the solution of a definite problem presented by commercial interests, with the primary object of making great financial gains. The investigator would not spend a moment on the work did it not promise to have a certain market value. The stimulus to prolonged and patient labor, as well as the initial cause of the investigation,

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[1] Reprinted from Economic Geology, I, No. 3, December-January, 1906.

must be considered as financial in character. As an example of this class of scientific research we may cite the attempts to solve the problem of economically treating titaniferous magnetite, in the hope of making the great deposits of this ore of iron available and of securing valuable monetary returns.

Intermediate between these two classes of scientific work is that class of study carried on with a certain regard to the commercial value of the results to be obtained, but not for commercial reasons primarily; and with an enthusiastic interest in the work for its own sake, but with the requirement that the branch of work selected must have something more than a merely educative value. It is apparent that such a class of work occupies the middle ground between the purely philosophical researches on the one side, and the purely commercial investigations on the other.

Associated with these three phases of scientific work we find three groups of investigators, both students and teachers, and three classes of schools. It is one function of our large universities to encourage the best in philosophical and educational work, and to this end they maintain schools of pure science. Research along lines that promise no financial reward is provided for by endowment. Here we find most of the teachers who have an enthusiastic interest in original investigations conducted without regard to the monetary value of the results to be obtained, and here come those students who have determined to devote their lives to the study of nature's laws, even at a great financial sacrifice.

The university is not a money-making institution, however, and we should not expect to find it actively engaged in furthering investigations for the main purpose of selling the results for a large cash consideration. Accordingly we must look elsewhere for the teachers and students engaged in scientific investigations which are stimulated by commercial needs and the promises of financial gain. From the nature of the case much of this class of work is done independently by individual workers rather than by organized schools. Large commercial enterprises sometimes justify the maintenance of research laboratories, where special problems of immediate importance to their success are worked out by skillful investigators, and where younger assistants may get valuable training. At other times these enterprises profit by securing the services of outside workers for a limited time or for a special problem; and such workers are often teachers in the universities or

technical schools, who devote the most of their time to one of the other two classes of investigation here considered.

The intermediate phase of scientific work, neither purely philosophical nor purely commercial, occupies a most important place in our educational institutions. It is not alone the function of the university to provide for philosophical and educational advancement, it must also provide training for those men who are to take the lead in commercial enterprises. Such a training to be most efficient must prepare the student to take the results of the more philosophical investigations and apply them to the practical problems of every-day life. So it is that our large universities maintain technical schools, or schools of applied science, as well as schools of pure science. The same field is occupied by our various independent technical schools. In these schools we find a class of teachers who are interested in their several lines of scientific work for something more than financial reward, else they would be occupying better paying positions in commercial concerns. Yet they must be keenly interested in the practical commercial applications of their work, for that is the side of the work which they are called upon to emphasize. To these schools come those students who look forward to a life of professional business activity, and who desire to provide themselves with the best possible equipment with which to meet the keen competition of the commercial world, hoping thereby to be successful in financial enterprises. This whole question of the application of scientific principles to the solution of practical problems is one of engrossing interest, and of paramount importance to the technical school. Certain phases of this question, especially those involving the application of geological principles, are here presented.

The term *applied science* may be so interpreted as to cover a very wide field. As here used, the term refers to the application of the principles of the pure sciences, such as psychology, biology, geology, physics, mathematics, etc., to the more practical problems encountered in engineering and other professions. The psychologist may spend years in investigating mental processes and discovering the reactions that normally take place in response to certain stimuli, without ever making use of the results obtained to determine the sanity or insanity of a person, to follow the workings of the criminal mind, or to locate an area of the brain that is suffering from some pathological condition. This is pure science. But when the psychologist himself, or the expert in the treatment of mental diseases, or the criminologist takes advan-

tage of the results obtained by the researches of the psychologist to solve some such practical problem as those indicated, we have to deal with applied science. The neurologist may spend a lifetime in studying the paths of certain nerves in the body of the fish, he being a teacher and investigator in pure science alone. The physician who profits by the discoveries of the neurologist to treat successfully certain nervous affections which before baffled every effort of the medical profession is studying and practicing applied science. The palæontologist studies, classifies, and describes the various forms of fossil shells, and is properly regarded as an investigator in pure science. But when he or any other employs the knowledge thus acquired to locate beds of ore, rock valuable for economic purposes, or artesian water-bearing horizons, a practical application of pure scientific knowledge has been made, and the work belongs in the realm of applied science.

The teacher of applied science occupies a unique position. He stands between the realm of pure philosophy and pure commercialism, and must have a good measure of familiarity with both. He must be in close touch with every advance in his special branch of pure science and with modern methods of investigation. To do this successfully he must himself be an original investigator, actively engaged in promoting the advance of knowledge in his particular field. Only thus can he hope to come into that vital touch with other workers along the same line that will enable him to fully appreciate all that they are attempting and accomplishing, and to judge intelligently the results of their labors. He cannot, however, shut himself up in the realm of pure science, for he must keep in close contact with those departments of the commercial world which find his branch of science of special value in the solution of practical problems. It is essential that he appreciate the needs of commercial enterprises, for only thus can he know where and how to apply his scientific knowledge for the accomplishment of the most good. He must know the problems of the commercial world, the possible solutions discovered by the scientific world, and be able to apply the latter to the former.

In referring to the broader aspects of this problem, "applied science" has been defined as the application of scientific methods and principles to the study of practical problems. If this definition be essentially correct, then "applied geology" is the application of geological methods and principles to the study of such problems. These problems are encountered for the most part by those engaged in engi-

neering work, more especially the mining engineers, civil and sanitary engineers, topographers, and others whose duties involve a study of the earth's surface or extensive operations carried on below that surface.

In a recent number of *Economic Geology*,[1] Mr. F. L. Ransome, in a most interesting article on "The Present Standing of Applied Geology," makes "applied geology" a synonym for "economic geology," and suggests very narrow limits for the term, in the following words: . . . "as a synonym of *economic geology*, or what the Germans call *praktische Geologie*, the term *applied geology* is so obviously convenient to express the application of general geological methods and principles to the study of valuable mineral deposits as to warrant its use with this special meaning."

It would seem, however, that if applied science means more than the application of scientific principles to the study of valuable mineral deposits, then applied geology should include much more than the application of geological principles to the study of such deposits. So long as geological principles are applied, we have to do with applied geology, whether that application be made to the excavation of a tunnel for a railway, the development of a body of iron ore, or the location of artesian water supplies.

One very important branch of the United States Geological Survey is engaged in applying geological methods and principles to the development of artesian and other supplies of water. Large railroad corporations retain the services of geologists for other purposes than the investigation of the mineral resources along their lines. Engineering companies engaged in the construction of subways for trolley lines, canals, dams, reservoirs, etc., have their consulting geologists. The dredging of ship channels in rivers and harbors and the keeping of those channels open, the construction of levees to prevent the flooding of great rivers, the building of jetties to direct and control the flow of rivers, all demand some knowledge of geological forces and the laws according to which they operate. Our engineering schools recognize these facts, and provide instruction in the application of geological methods and principles to engineering problems other than those which involve the study of mineral deposits. In some cases this instruction is given in connection with courses in general or structural geology; in others special courses in applied geology are offered. At the Massa-

[1] Economic Geology, I, No. 1, pp. 1–10.

chusetts Institute of Technology there has been given to civil engineering students, for some years, a course entitled, "Applied Geology." The bearing of geology upon civil engineering operations is emphasized, with little or no reference to mineral deposits.

It is true, however, that the application of geological principles and methods to the study and development of mineral deposits constitutes one of the most important departments of applied geology. Probably the majority would consider it by far the most important of all, and it is not surprising, therefore, to find text-books entitled, "Applied Geology," which actually deal with only this one branch of the subject. For example, we have Burat's "Géologie Appliquée," the more expanded title of which shows it to be simply a "Traité du Gisement et de l'Exploitation des Minéraux Utiles," with a few preliminary chapters on certain more general geological considerations. On the other hand, we have an American text ("Applied Geology," by S. G. Williams) which regards applied geology as "the applications of geology to the various uses of mankind," and which, therefore, discusses the relations of geology to railroad and other tunnels, foundations of engineering and architectural structures, dams, reservoirs, canals, springs, wells, drainage for agricultural and other purposes, sanitation, agriculture, etc., while the various economic minerals are treated at considerable length. An English text on "Practical Geology" (D. T. Ansted), a term used by most writers as a synonym of "applied geology," outlines the limits of the subject in the following words: "I understand by the expression 'practical application of science,' an account of the different methods by which the various facts of the science, as discovered by actual observation, and the general laws which have been deduced from a careful study of the true value and analogies of those facts, may be shown to bear upon the pursuits of practical men, assisting them in coming to right and useful conclusions in their ordinary business. I hope to be able to show that the facts of geology already recorded, and the general conclusions arrived at, may be thus made use of in the ordinary affairs of life and applied immediately to practical purposes." This author considers that "the application of geology to mining must ever be the first and the most deeply interesting of all branches of practical geology." He then devotes some nine chapters, including nearly two hundred pages, to various phases of mining geology. "But mining in all its branches," we read, "is only one department of practical geology." So there follow some half a dozen chapters,

including nearly a hundred pages, devoted to a discussion of the uses to be made of geology in road and canal making, the construction of harbors, breakwaters, quays and bridges, the location of railways and of building sites, the draining of lands, the driving of wells, and in coming to a proper understanding of the decomposition of building stones, the formation and mixture of soils, the behavior of springs and wells, etc. The German interpretation of "*praktische Geologie*" is not always the same, Keilhack's "Lehrbuch der Praktischen Geologie" dealing rather with the making of maps, the preparation of rocks and minerals for study and the methods of investigating their characters, the study of fossils, etc., than with mining geology.

The exact interpretation of such a general title as "Applied Geology" is not a matter of prime importance, however, and enough has been said to show how different such interpretations may be. It might be said, in partial explanation of the more limited usage of the term, that the time was when mining geology was the only "*praktische Geologie*," and the terms were more truly synonymous than today. As a result of the great growth of the science, many practical applications of geology are made today that were not dreamed of when the term "*praktische Geologie*" first came into use. It is also true that a writer often applies the general term to the more specialized work, without any intention of restricting it to that phase of the work alone.

It is believed, then, that the scope of applied geology most properly includes all applications of geology to practical problems. If this be true, then the subject must occupy an important place in every thoroughly equipped technical or engineering school. The students in mining engineering are not prepared to enter on their work until they have acquired a knowledge of the fundamental principles of general geology, and more especially a knowledge of the minerals and rocks with which they will have to deal, the structural features of the earth's crust and their relations to valuable deposits that may be involved in those structures, the geological relations and possible origin of the more important deposits in the country, together with some conception of the present state of our knowledge concerning the origin and classification of mineral deposits in general. They should, if possible, be given some practice in geological mapping, to the end that they may be able to plot the surface geology of a mining region, and from that gain some idea regarding the underground structure in which the deposits are involved.

It is not the purpose of a course in mining engineering to fit a student to take up, immediately upon graduation, the duties and responsibilities of a full-fledged mining engineer. Practical experience in mining regions is a part of the training that must come after the years spent in a technical school. The object of the engineering education is to give the student a broader and in some respects a more exacting training than he is likely to get in his practical experience in some one locality for years to come; to give him an extensive view over the whole field of his chosen work, such as he would otherwise get only after many years of experience; to open his eyes to the possibility of bringing to the solution of problems he may encounter many factors of which he must otherwise remain largely in ignorance; thus to fit him to meet successfully the emergencies that may arise in his professional duties with an intelligent, accurate, creative mind. Experience has shown that a knowledge of geology has often proven necessary to the proper solution of mining problems. Indeed, every mining proposition is a geological problem, be it simple or complicated. Hence a thorough training in geology is essential if the engineer is to bring to his aid in solving mining questions the factor that often affords the greatest help.

A recent editorial in the *Engineering and Mining Journal* calls attention to the great need of keeping careful and intelligent records of the geological features exposed in the course of underground workings, especially as those workings may later be abandoned and become inaccessible through caving, or for some other reason. As is there pointed out, only the largest mining companies can afford to maintain a special geological department, and many cannot even retain the services of a geologist. Nevertheless the records should be kept as well as is possible, as "the results would be of more or less value according to the competence and fidelity of the observer." A geological training should be such as to enable the engineer to appreciate the great importance of the matter in question, and also enable him to keep such records intelligently and work out from the evidence thus accumulated many points of value to his employers. That this is not asking too much of the young engineer is indicated by the important results already achieved by recent graduates in certain cases.

The civil engineer must be prepared to meet many problems involving geological factors, and must therefore be equipped with an adequate geological training. As a foundation a general course in the

fundamental principles of geology seems essential. Familiarity with the different rock species, and a knowledge of their relative values as building material, road metal, etc., will save the engineer from many costly errors. The effect of rock characters and rock structures on tunneling, the need of lining tunnels which penetrate certain rocks which at first appear massive and strong, the danger of caving where shearing planes dip toward the excavation, the possibility of continued slipping of morainal deposits along a railroad cut in such material, the probable changes that may be expected in a river meandering in its flood plain, the possibility of locating water-bearing beds, building stones, and cement rock even when they do not appear at the surface, the conditions essential for the accumulation of artesian waters, and the methods of forecasting the probable behavior of wells to be drilled — these and many other subjects afford abundant material which may be brought to the attention of the civil engineering student with profit. The topographer needs systematic training in the relations of geology to the varied topographic features of the earth's surface. He is called upon to represent the earth's surface not by an actual copy, but rather by an abstract of its features. No contour map is made by determining the position of every contour with accuracy; on the contrary, a limited number of points are so determined, while the topographer must sketch in the remaining areas. The scale does not admit of copying all features, and the topographer who is to make a map which will show the significant features with expressiveness must have an understanding of the subject with which he is working. It is not good policy to have an important work on astronomy reviewed by a person who knows nothing of the science of astronomy. Having no appreciation of the subject with which he is asked to deal, he can hardly hope to present an accurate and properly proportioned abstract. Neither can the topographer achieve the best results so long as he has no knowledge of the land forms which he is required to reproduce in a map abstract.

The sanitary engineer finds that he must have certain kinds of soil for various processes of sewage disposal and water purification. Where the loose sands of glacial deltas, outwash plains, or other deposits of like composition are available, certain of these processes may prove practicable; but where only beds of compact clay or till are found, the cost would be prohibitive. The draining of swamps that prove a menace to public health may sometimes be accomplished by boring through to underlying beds of loose sand or gravel, from which the waters find

a ready outlet. The direction in dip of the rock structures may determine the liability of cesspools to contaminate sources of drinking water at considerable distances. The direction of flow of underground waters may cause or prevent such contamination. Such are a few of the considerations that appeal to the interest of the sanitary engineer.

The many applications of geology to these and other branches of engineering cannot be enumerated here, the points above mentioned merely serving to indicate in a general way the extensive scope of the subject. The methods of presenting these practical considerations to the students must vary with every school and every instructor. It will probably be agreed by most of those engaged in teaching applied geology that the geological training given to the engineering student must be far more fundamental and thorough than would be afforded by a brief course relating the details of certain instances of the application of geology to engineering problems. It is necessary that the student be grounded in the general principles of dynamical and structural geology especially, if he is to appreciate the significance of geological phenomena when he encounters them, and be able to reason intelligently and correctly concerning them. The instructor cannot hope that the members of his class will always have to deal with the same problems which he may present to them in the lecture room. Perhaps they may never meet just the same set of conditions which he describes as occurring in concrete cases. The important thing is to open the eyes of the men to the fact that in the past a knowledge of geology has made possible the solution of many difficult engineering problems, that the lack of such knowledge has often caused disaster and failure, that in the future this history will certainly repeat itself, and that if they are to meet such emergencies properly they must provide themselves with the necessary equipment.

Nothing appeals so strongly to the practical man as a specific case to illustrate a given proposition. The value of concrete instances in illustrating the application of geology to engineering problems can hardly be overestimated. The student may forget an abstract geological principle before he has left the lecture room; but he will remember an actual case, illustrating the application of that principle, for years. It seems to me that a most important part of the work in teaching applied geology is the securing of details regarding actual cases in which geology has been used to such advantage by practical men. Many such cases can be found by looking over the literature; but another source

of wealth is to be found in the cases which come to the knowledge of geologists and engineers, but which have never found their way into print. One cannot help wishing that these edifying experiences might be made available for the benefit of the younger and less experienced men by publication of the valuable technical details stripped of the personal features which might otherwise make the publicity distasteful to some of those concerned. Many are the valuable object lessons that would thus be presented to the younger engineers and geologists.

Shall the courses in applied geology be given as distinct courses after the student has acquired a knowledge of the principles of dynamical and structural geology, or shall the two phases of the work be presented simultaneously? In some cases it has seemed best to present the more theoretical aspects of the subject, together with the fundamental principles as established by careful investigation, as separate and systematic courses in dynamical and structural geology, embodying in a later course the application of these principles to practical problems. The alternative is to give the applied geology with the pure geology by showing the possible application as soon as each principle is fairly established. It seems to me that the latter method has the great advantage of arousing and holding the interest of the engineering student by showing him the practical value of the knowledge he is acquiring, and of fixing firmly in his mind the general principle by means of the more readily remembered illustration. For example, if the general discussion of folded strata, including the different types of monoclinal, anticlinal, and synclinal folds and their general effects upon the rocks involved, be followed by a consideration of the effects of such folds upon engineering enterprises, the student finds the subject of more vital interest to him than would be the general discussion alone. The mining engineer sees the practical value of the subject when he learns the effects of anticlines on the accumulation of oil and gas, the manner in which synclinal troughs serve to collect deposits of metallic ores, the manner in which saddle reefs and inverted saddles are formed, and the importance of such folding in developing fissures along the crests of anticlines and in the troughs of synclines. The detailed discussion of the various mining regions may come later in a course in economic geology, but some reference to the effects of folding on mining problems seems to prove helpful at this point. The fact that pitching troughs and anticlines may prove deceptive is then pointed out, the nature of their outcrops explained, and the effects on exploration and development work

discussed. If this be followed by an account of some special case, as where two engineering students working on their thesis succeeded in demonstrating the presence of a pitching fold where none was suspected before — a discovery which eventually led to the opening up of valuable ore bodies — then the student is more ready to appreciate the value of the subject of folds than he would ever be if only the abstract discussion were presented at that time, leaving the practical application till a later course.

So also in the case of the civil engineer: if he is told that the folding of brittle sandstone in a low syncline is apt to break or fissure the rock so that it becomes like an arch inverted and with the "keystone" hanging downward, he may forget it. But when the case of a Pennsylvania tunnel driven into a hill composed of sandstone in this condition, which resulted in the removal of the support from under the keystone and the consequent caving in of extensive masses of the rock, is brought to his attention, the feature of folding referred to will not soon escape his memory. He might forget a statement that shales which appear solid and massive when first exposed to the air tend to crack and crumble later on; but he will not forget that a certain tunnel driven in such shales, and not lined because the rock appeared so solid and massive when penetrated, collapsed and caused disaster when the shales dried and crumbled.

The value of the general principle itself must not be overlooked in emphasizing the concrete illustration. The principle has a value independent of any application. But to that class of men who come to seek the practical applications of geology more especially, such illustrations serve a most important end in fixing the principal points in mind, in arousing a healthy interest in the work, and in awakening the student to the possibilities of practical utility offered by an intelligent application of the principles of the science.

THE MICROSCOPIC ESTIMATE OF BACTERIA IN MILK[1]

By FRANCIS H. SLACK, M.D.

Within a comparatively short time many cities have awakened to the wisdom and necessity of establishing a bacterial standard for milk. As there are, as yet, no standard methods for the bacterial and microscopic examination of milk, each laboratory has had to work out its own methods. Work along this line was begun in Boston, under the direction of Dr. H. W. Hill, in May, 1904, about nine thousand samples having been examined to date.

Plating is almost universally used for determining the bacterial content of milk. This method is open, however, to one serious and many minor objections. The serious objection is on the time required, since when the test is completed and the number of bacteria ascertained the milk in question has been marketed and consumed. Among minor objections may be mentioned the fact that the number of colonies developing depends largely upon the composition of the media and the degree and length of incubation, besides which such care is necessary in all the details of the technique as to require the services of a trained bacteriologist.

Milk contractors, or dealers, as they are sometimes called, who have to bear the brunt of the problem of providing a clean milk supply, are asking for some quicker and less technical method of determining the bacterial quality of the milk received by them from individuals — a method by which they can have so close a supervision as to keep their mixed product well within the required limits. Russell, of Wisconsin, describes a "curd test" which is so rapid as to interfere little with the almost immediate sale of the milk.

It is the object of this paper to present another method, which is both quick and accurate, and which, although it requires careful manipulation and a certain amount of experience, does not require the

[1] Read before the Society of American Bacteriologists, December, 1905.

accuracy as to detail or large amount of expensive apparatus used in plating. The writer, in carrying out routine examinations of milk sediments for pus and streptococci, noticed that the number of bacteria found in the microscopic field apparently bore a definite relation to the number of colonies developing in the plate from the same sample. It was thought that this might be of practical value if, after prolonged comparison, it turned out to be constantly true, since there would then be no necessity to plate, incubate, and count samples which the microscope alone indicated were better than the legal requirements. Winslow,[1] using $\frac{1}{20}$ c.c. of unsedimented material, had previously applied the direct microscopic enumeration of bacteria to water and sewage. It was decided to test the method thoroughly, comparing the microscopic estimate with the actual count obtained from the plate. This comparison was carried out very carefully with over 2,200 samples, each sample being subjected to the double test — *i. e.*, centrifugalizing and plating, the microscopic estimate being made before the plate was counted, usually within a few hours after the samples were received — and an error of less than 1 per cent. was made in passing as below 500,000 bacteria to the cubic centimeter milks which in the plates showed above this limit. Over a third of the total error occurred in the first 420 samples before the method was fully developed.

The apparatus and the method for making the microscopic estimate are as follows: The special apparatus for centrifugalizing the milk, modified from one used by Stewart, of Philadelphia, consists of an aluminum disk and cover, 10 inches in diameter and $\frac{3}{8}$ inch in depth, fitted to hold twenty small glass tubes arranged radially. These tubes hold about 2 c.c. each, and are closed at both ends with rubber stoppers.

The milk sample is thoroughly shaken, the tubes filled, stoppered, inserted into their proper numbered receptacles in the disk, and centrifugalized for ten minutes at a speed of from two to three thousand revolutions a minute. Thus in each tube the whole sediment from a known quantity of milk is obtained, and may be spread over a given area. A space of about 4 sq. cm. is most convenient, being the right size to allow thorough emulsion of the sediment with a drop or two of sterile water, and to permit drying into a thin, even smear. It is convenient to smear a number of samples consecutively on a long glass slide which has previously been correctly spaced with a blue pencil.

[1] Jour. Inf. Diseases, May, 1905, Sup. No. 1.

To obtain the sediment with the least disturbance, the stopper is first removed from the inner, or cream, end; then the tube is held with the cream end downwards, the cream removed with a platinum loop, and the milk poured out; lastly, still holding the cream end down, the other stopper is carefully removed with the adhering sediment and the sediment smeared evenly with a drop of sterile water over the measured space on the glass slide, the stopper being rubbed directly on the glass until the sediment has been transferred. When this is properly done the amount of diluted sediment remaining on the stopper is practically negligible. The smear is then dried with gentle heat and stained with methylene blue.

The microscopical examination of a milk sediment thus easily prepared reveals more than any other single test. It shows the character of the milk, the approximate number and the morphology of the bacteria, and the presence of pus or streptococci.

It is not claimed that all the bacteria in the milk subjected to centrifugalization are precipitated into the sediment; but it is claimed that in 99 per cent. of the samples a representative number is so precipitated, and that this number bears a fairly constant relation to the $\frac{1}{10000}$ dilution plate culture when grown in a saturated atmosphere at 37° C. for twenty-four hours, 1 per cent. agar being used with a reaction of + 1.5.

We may say, as a rough estimate, that each coccus, bacillus, diplococcus, or chain in the $\frac{1}{12}$ oil immersion field represents one colony in the $\frac{1}{10000}$ plate from the same sample. The writer wishes to emphasize the fact that this is a coincidence stumbled upon in the course of routine work rather than a carefully worked out mathematical result. It is, of course, impossible to obtain a perfectly even smear, and the sample must be sized up by examining a number of fields. Let the observer find such a representative field, then imagine that instead of looking at a microscopic field through a $\frac{1}{12}$ oil immersion lens he is looking at his $\frac{1}{10000}$ dilution plate, and that each coccus, bacillus, diplococcus, or chain within his vision represents a colony on such a plate; and if he will make the plates also, he will find how closely in the main they agree with his microscopic estimate. That is, in most cases the count of a representative field multiplied by 10,000 gives approximately the number of bacteria per cubic centimeter. By the use of this method a good idea of the condition of a single sample of milk can be obtained in less than twenty minutes. Thirty samples

can be examined in an hour. At the contractor's receiving station one man could easily examine 100 to 200 samples daily, thus keeping close watch over the dairies. There is no reason why, with such a method well established and in good working order, the mixed product should not be very low in bacteria, since the only excuse for excessive bacterial contamination of milk is ignorance, carelessness, or improper handling; and so rigid a supervision, with proper educational notices, would quickly bring the recalcitrant dairies to time or retire them in favor of their more progressive neighbors.

In city inspection only those samples need be plated which are doubtful or above the limit established. In this work the plate would corroborate the microscopic findings and strengthen the evidence for court cases. Where plates are to be made the microscopic estimate gives an indication of the proper dilution to use.

In its present state this method would probably be of no practical value in determining numbers accurately; for instance, it would be impossible to state if a milk contained twenty, thirty, forty, or fifty thousand bacteria per cubic centimeter. The writer, however, believes that this method is practical for certifying milk as below 50,000 bacteria per cubic centimeter, and that any milk which, in a sediment so prepared, shows no bacteria on microscopic examination is harmless from a bacterial standpoint, leaving out of the question, of course, typhoid or other infectious diseases. The large number of samples which could be examined and the increased efficiency of the supervision thus obtained would compensate many times over for the loss of a slightly greater accuracy in plate counts.

Boston Board of Health Laboratory,
January 27, 1906.

A STUDY OF THE LAWS GOVERNING THE RESISTANCE OF BACILLUS COLI TO HEAT[1]

By STEPHEN DeM. GAGE and GRACE VAN EVEREN STOUGHTON[2]

In a previous communication from the Lawrence Experiment Station[3] it was shown that while a considerable majority of both *Bacillus coli* and *B. typhosus* are destroyed by a comparatively short exposure to unfavorable conditions, a few individuals in every culture proved to be much more resistant, and survived after treatment which had destroyed more than 99 per cent. of the bacteria in the given culture.

It is generally conceded that *B. coli* and *B. typhosus* do not form spores; nevertheless, the extraordinary resistance which a few organisms in every culture exhibit would lead to the conclusion either that they were in a form closely simulating true spores, or that, as is the case in all biological species, the stronger individuals were brought into prominence by the conditions imposed.

If we accept the first hypothesis, that the supposedly non-spore-bearing species may after all take on a specially resistant form akin to the true spore state, we might expect that cultures which were out of their natural habitat, and had been, presumably, attenuated by exposure to unnatural conditions, would contain a larger percentage of these resistant organisms than would a fresh laboratory culture. On the other hand, if the resistant few are of a more hardy nature, by subjecting successive generations to conditions such that only the

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[1] Read at the seventh annual meeting of the Society of American Bacteriologists, December 29, 1905.

[2] The studies here reported were made late in 1904, while Mrs. Stoughton was a volunteer research assistant at the Lawrence Experiment Station. While the studies were still incomplete, Mrs. Stoughton returned to New York, and to our great sorrow died shortly afterward. The writer has endeavored to present fairly the theories upon which the experiments were founded and the bearing which the accumulated data have on those theories, without attempting to obtain additional evidence. Mrs. Stoughton should receive full credit for the active part which she took in the investigation, but she should not be held responsible for any conclusions which have been drawn therefrom.

[3] Thirty-fourth Annual Report Massachusetts State Board of Health, 1903, p. 268.

hardy individuals would survive, and causing these to become the progenitors of a new race, according to the theory of evolution by the survival of the fittest, we would expect that our successive generations would gradually become stronger, and that in the end we should have a race in which a larger proportion of the individuals would be able to successfully resist the given conditions than was the case in the original culture.

Some experiments made at the Lawrence Experiment Station appear to throw some light on these points. In these experiments the phenomena resulting from the exposure of cultures of *B. coli* to different temperatures were studied. In one experiment (No. 195) successive generations of a given culture were subjected to thermal death-point tests, those bacteria which most successfully resisted the application of heat becoming the progenitors of a new culture to which the thermal death-point tests were again applied, the attempt being made to produce in this manner a race of bacteria in which the characteristics of the more hardy individuals of the original culture should become predominant. In the second experiment (No. 197) sterile water was seeded with bacteria from the original culture, and was allowed to stand in the laboratory for stated times before the thermal death-point tests were applied, in order that the bacteria might have a chance to take on the more resistant character which spore-bearing types usually assume when removed from their natural habitat for any length of time.

Procedure. — The culture selected for experimental purposes was one which had been isolated from normal stools about three months previously, and which an exhaustive study had proved to be a typical *B. coli*. Before use the culture was plated out to insure purity, and was then revivified by carrying it through three successive cultivations in broth, each culture being incubated twenty-four hours at body temperature. The resulting broth culture was then diluted with sterile tap water, and 3 c.c. of this water culture were placed in each of a number of sterile test tubes, all of which were carefully selected to insure uniformity of bore and thickness of glass. Each of these tubes was then immersed for exactly five minutes in a water bath kept accurately at the desired temperature, after which the contents were immediately plated on agar, and an equal volume of broth was mixed with the culture remaining in the tubes. Temperature readings, with the thermometer inside the tubes, showed that the cultures reached the

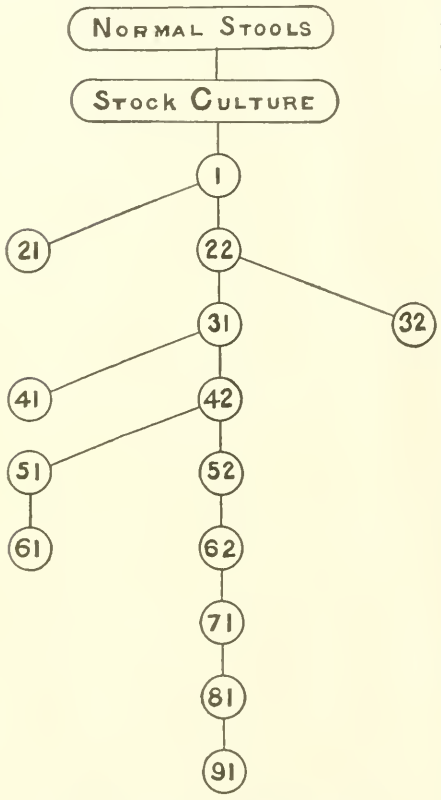
temperature of the bath in less than thirty seconds, the five-minute period, however, being reckoned from the time the tubes were placed in the bath. The temperatures in every case ranged from 40° C. to 100° C. by intervals of 5°. The agar plates and the broth cultures were incubated eighteen hours at body temperature, after which the plates were counted and the presence or absence of growth noted in the broth cultures. The procedure in the thermal death-point tests was the same throughout the investigation. A careful examination of a large number of cultures isolated during the various stages of the two experiments proved that no contamination had occurred during the many transfers made, and no modification in the characteristics of the culture could be detected by the usual methods of species determination even after it had passed through nine generations which had been heated to near the thermal death-point.

Expression of Results. — In comparing the results obtained in experiments of this character, especially when dealing with cultures in which the initial numbers of bacteria vary through wide limits, the relations between the changes produced by identical treatment are often obscured by differences in the numbers of bacteria in the various cultures. It has been found in previous investigations that the true relation between results of different portions of experiments of this character is best shown when the results are expressed on a percentage basis, that is, when we express each result, not as the actual number of bacteria found, but as the ratio of that number to the number of bacteria in the control culture. The results shown in the tables further on have been computed in this manner, the initial numbers of bacteria having been reduced to 100,000 and the various bacterial determinations having been reduced in the same ratio. Another advantage in this method of expression is that we are able to average the results of different experiments with absolute mathematical fairness. The sign plus (+) in the tables indicates that no colonies appeared on the plates, but that a growth in the broth cultures showed that the cultures were not entirely sterile.

A further difficulty becomes apparent when we attempt to plot the curves of bacteriological experiments. If we plot these curves on a scale which will show the variations in both the larger numbers and in the smaller numbers, our curves become too large for practical reproduction, while if we reduce the scale we are able to show only the general curves without the minor fluctuations which are often so

significant. This difficulty is best overcome by plotting on a logarithmic scale, the minor differences being well distinguished by this method; and while the height of the scale is materially reduced, the consequent foreshortening of the curves does not affect the impression which they are intended to convey. The writer has used the logarithmic scale for plotting bacterial curves for many years with entire success, and the curves in Diagrams Nos. II and III have been drawn in this manner.

DIAGRAM I



GENEALOGICAL SEQUENCE OF THE CULTURES IN EXPERIMENT 195

Experiment 195. — In this experiment it was attempted to establish a race of *B. coli* in which a majority of the bacteria should simulate the characteristics of the more hardy individuals of the original culture by applying the theory of the survival of the fittest. The counts on the plates made after the thermal death-point determinations with the original culture (culture No. 1) showed that about 30 per cent. of the organisms had been destroyed at 50°, and about 96 per cent. at 55°. Only a few individual organisms survived at temperatures ranging from 60° to 90°, and at 95° and above the cultures were sterile. On the second day dilutions were made of the broth cultures from the samples which had been heated to 90° and 60° on the previous day, and portions of these water cultures were treated as before, these cultures being called Nos. 21 and 22, respectively (Diagram I). With culture No. 21 over 20 per cent. of the bacteria were destroyed by five minutes' exposure to 45° C. and over 70 per cent. by exposure to 50° C. At 55° C. practically all of the bacteria had been killed, as was the case at 65°, all of the higher temperatures having sterilized the cultures.

exposed to them. With culture No. 22 a somewhat similar decrease was noted at 45° and 50°, the percentage reduction being 14 per cent. and 96 per cent., respectively, at those temperatures. At 55° all but a few individuals had been destroyed, as was the case up to 75°, and at 80°, although no colonies appeared on the plates, a growth occurred in the broth culture. Above 80° the cultures were sterile.

Two cultures from No. 22 which had survived heating to 80° and 60° on the second day were selected for the tests on the third day, these cultures being called Nos. 31 and 32, respectively. The plate counts showed that 100 per cent. and 44 per cent. of the bacteria from culture No. 31 had survived 45° and 50°, respectively, and a few colonies appeared on the plates from cultures which had been heated to temperatures ranging from 55° to 80°. The 85° culture failed to develop on the plates, but was able to grow in broth. Above 85° all of the cultures were sterile. Culture No. 32 proved to be somewhat less resistant than No. 31, 71 per cent. of the organisms being destroyed at 45° and 87 per cent. at 50°. At 55° to 70° and at 80° a few organisms survived, while at 75° and at all temperatures above 80° the cultures were sterile.

On the fourth day the 80° and 55° cultures from the previous day's treatment of culture No. 31 were chosen, being called Nos. 41 and 42, respectively. These two cultures reacted more like the original culture than did any of the other cultures tested, in the fact that considerable numbers of each were able to grow after heating to 55°. This may possibly have been due to some modification of the conditions of the experiment, although every attempt was made to have these conditions uniform. With culture No. 41, 23 per cent., 11 per cent., and about 1 per cent. of the organisms were able to resist temperatures of 45°, 50°, and 55°, respectively. Above 55° the results were very erratic. At 60° and at 75° the cultures were sterilized completely. At 70° and at 75° no colonies appeared on the plates, although a growth occurred in the broth, while at 80° nearly three hundred colonies appeared on the plate. Above 85° all of the cultures were sterile. With culture No. 42 much the same erraticism was noted. Sixty-three per cent., 46 per cent., and over 2 per cent. of the organisms were able to develop after exposure to temperatures of 45°, 50°, and 55°, respectively, and a few colonies appeared on the plates from the 60° and 65° cultures. The temperature of 70° effectively sterilized the culture; but temperatures of 75° and 80° failed to com-

pletely sterilize, as shown by a growth in broth, although no colonies developed on the plates made from these cultures. Above 75° all the cultures were sterilized.

Cultures of No. 42 which had shown growth after heating to 80° and 60° C. on the fourth day were chosen for the tests on the fifth day, these cultures being numbered 51 and 52, respectively. With culture No. 51, 34 per cent. survived a temperature of 45° and over 5 per cent. survived a temperature of 50°, while a few colonies appeared on plates made from cultures which had been heated to 55°, 60°, and 65°, respectively. No colonies appeared on the plates made from the culture which had been heated to 70°, but a growth occurred in the broth culture, showing that all of the organisms had not been killed. Temperatures above 70° effectually destroyed all of the bacteria in this culture. With culture No. 52, 72 per cent. of the organisms were alive after exposure to 45° and 20 per cent. after exposure to 50°, while after exposure to 55° and 60° a few organisms were able to grow on the plates. The plates made from the culture which had been heated to 65° were sterile; but there was a growth in the broth cultures, showing that sterilization was not complete. Plates and broth cultures made from samples which were exposed to temperatures above 65° showed no growth.

On the sixth day a change was made in the method of selecting cultures from the previous day's tests, the culture which had been heated to 55° being taken from each of the stock cultures Nos. 51 and 52, the culture from stock No. 51 being numbered 61, and that from the stock No. 52 being numbered 62. These two cultures reacted much alike when subjected to thermal death-point tests. At 45° 27 per cent. of the organisms of culture No. 61 were destroyed and 37 per cent. of the organisms in culture No. 62, while at 50° the percentage destruction of bacteria in the two cultures was 69 per cent. and 77 per cent., respectively. After heating to 55°, only a small number of bacteria remained alive in each culture, and at 60° and above sterilization was complete.

Only one culture was tested on the seventh day, this being one from stock No. 62 which had been heated to 55° on the preceding day. No destruction of bacteria occurred when this culture was heated to 45°, the number of colonies developing on the plates being more than twice as great as in the control culture. At 50° more than 95 per cent. of the organisms were killed, while at temperatures ranging from 55° to

TABLE I—Showing the Relative Behavior of Successive Generations of a Culture of B. Coli when Subjected to Thermal Death-Point Tests

	Temperature.	First Generation.	Second Generation.		Third Generation.		Fourth Generation.		Fifth Generation.		Sixth Generation.		Seventh Generation.	Eighth Generation.	Ninth Generation.
		No. 1	No. 21	No. 22	No. 31	No. 32	No. 41	No. 42	No. 51	No. 52	No. 61	No. 62	No. 71	No. 81	No. 91
Initial number of bacteria	. .	889,000	470,000	440,000	220,000	260,000	280,000	410,000	42,000	79,000	15,500	12,000	209,000	1,950,000	2,550,000
Relative numbers of bacteria	Start	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
	45° C.	136,000	79,000	86,000	100,000	29,000	23,000	63,000	34,000	72,000	73,000	63,000	258,000	64,000	243,000
	50° C.	70,000	29,000	3,600	44,000	13,000	11,000	46,000	5,200	20,000	31,000	23,000	4,500	9,700	49,000
	55° C.	4,400	70	6	50	5	900	2,300	7	4	570	20	20	12	200
	60° C.	1	0	8	10	300	0	1	2	90	0	0	160	2	0
	65° C.	250	1	400	1	1	+	1	300	+	0	0	20	0	0
	70° C.	30	0	1	2	20	+	0	+	0	0	0	10	0	22
	75° C.	50	0	14	3	0	0	+	0	0	0	0	0	0	0
	80° C.	15	0	+	3	1	90	+	0	0	0	0	0	0	18
	85° C.	3	0	0	+	0	0	0	0	0	0	0	0	0	0
	90° C.	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	95° C.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	100° C.	0	0	0	0	0	0	0	0	0	0	0	0	0	0

70° only small numbers remained alive, and above 70° the cultures were sterile.

On the eighth day a culture which had survived heating to 70° on the preceding day was selected for the thermal death-point determinations. After heating to 45° about 64 per cent. of the bacteria in this culture were yet alive, and after heating to 50° nearly 10 per cent. still survived. Temperatures of 55° and 60°, while sufficient to destroy a considerable majority of the organisms, did not entirely kill the culture, as shown by small numbers of colonies which were able to develop on the plates. Temperatures of 65° and above proved effective in sterilizing this culture.

On the ninth day the tests were made on a culture which had been heated to 55° on the eighth day. The results showed that the culture was unaffected by a temperature of 45°, but that a reduction of 51 per cent. occurred when heated to 50°. Considerable numbers of the organisms were unaffected by temperatures of 55°, 70°, and 80°, while the cultures subjected to temperatures of 60°, 65°, 75°, and 85° and above were sterilized. Circumstances over which we had no control prevented tests being made on the tenth day, and the sequence being broken the experiment was discontinued. The genealogical sequence of the various cultures is shown in Diagram I, and the results of the analyses are shown in Table I.

Experiment 197.—In this experiment it was attempted to produce a condition in which a non-spore-bearing type of organisms should be induced to simulate formation of spores by assuming a more resistant form than it had shown in laboratory cultures. Four bottles of sterile water were seeded with bacteria from the surface of an agar streak of the same stock culture as that used in the former experiment, these water cultures being allowed to stand in the laboratory for twenty-four hours, forty-eight hours, three days, and six days, respectively, after which portions of each culture were transferred to tubes and the thermal death-points determined, as in the preceding experiment. The thermal death-point tests on the original culture (Experiment 195, No. 1) showed that a majority of the organisms in the culture were destroyed by five minutes' exposure to a temperature of 55° C., but that a few organisms were able to resist temperatures as high as 90° C. With the twenty-four-hour water culture about 4 per cent. of the bacteria were destroyed at 45°, 30 per cent. were destroyed at 50°, 86 per cent. were destroyed at 55°, and nearly 99 per cent. were killed

at 60°. A few organisms, however, survived temperatures ranging from 60° to 90°, as shown by colonies on the plates or by a growth in broth. At 95° and 100° the cultures were sterilized. With the forty-eight-hour water culture the reactions were quite similar to those of the twenty-four-hour culture. At 45° no reduction occurred in the number of organisms, at 50° the reduction was 34 per cent., and at 55° 88 per cent. of the bacteria were killed. At temperatures of 60°, 65°, and 75° a considerable number of organisms still remained alive, although the total reduction had been over 99 per cent., and at the other temperatures up to 90° small numbers developed on the plates or growths occurred in broth. Above 90° sterilization was complete. The three-day water culture proved to be somewhat different from the two cultures just discussed. At 45° no reduction occurred, the numbers of bacteria being higher after the exposure to that temperature than in the control. At 50° a reduction of about 25 per cent. occurred, and at 55° a reduction of about 80 per cent. was noted. Above 55°, however, with the single exception of the culture which had been heated to 75°, no colonies were found on the plates, although growths in the broth cultures showed that complete sterilization was not accomplished by any temperature below 90°. The six-day culture showed the same general character as did the three-day culture. At 45°, 50°, and 55°, respectively, the reductions in the numbers of bacteria were 31 per cent., 55 per cent., and 86 per cent., while at temperatures ranging from 60° to 85° growths occurred only in the broth, no colonies developing on the plates. Temperatures of 90° and above effectively sterilized this culture. The results obtained in this experiment are shown in Table II.

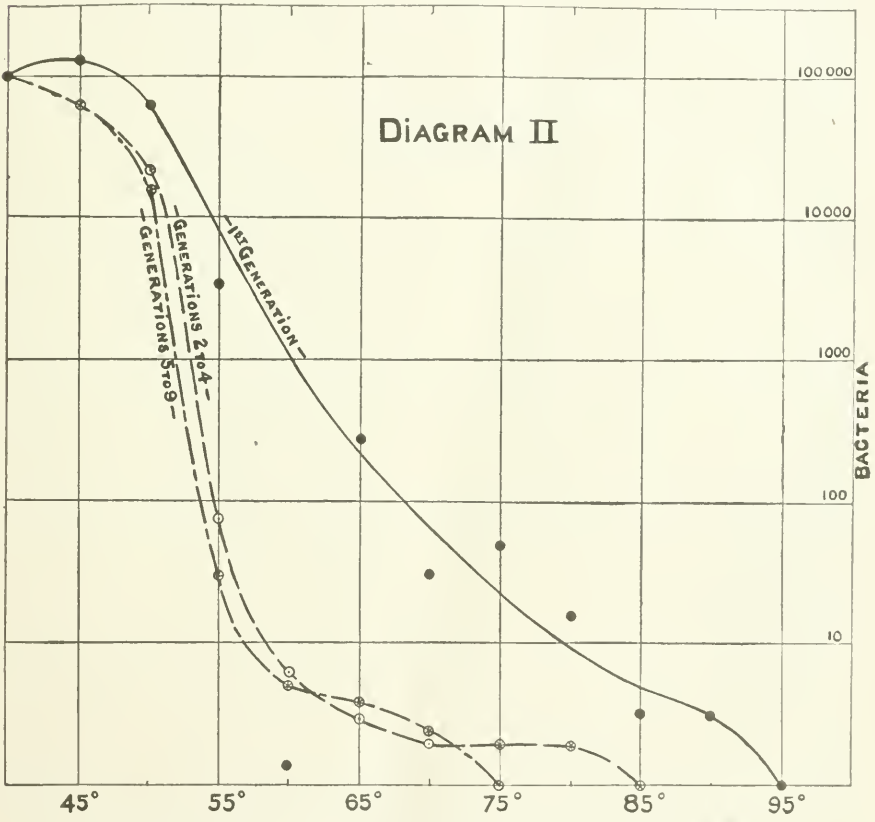
TABLE II — Showing the Relative Behavior of Water Cultures of B. Coli Which Have Been Standing Different Lengths of Time when Subjected to Thermal Death-Point Tests

	Temperature.	Twenty-four-hour water culture.	Forty-eight-hour water culture.	Three-day water culture.	Six-day water culture.
Initial number of bacteria	. .	13,000,000	25,000,000	14,760,000	17,000,000
Relative numbers of bacteria	Start	100,000	100,000	100,000	100,000
	45° C.	96,000	103,000	151,000	69,000
	50° C.	70,000	66,000	74,500	45,500
	55° C.	14,000	12,800	20,600	13,700
	60° C.	1,306	105	+	+
	65° C.	1	195	+	+
	70° C.	90	5	+	+
	75° C.	+	280	80	+
	80° C.	1	+	+	+
	85° C.	+	6	+	+
	90° C.	+	+	0	0
	95° C.	0	0	0	0
	100° C.	0	0	0	0

Conclusions. — In a consideration of experiments such as these, where considerable erraticism has occurred in the individual results, and where the data acquired are incomplete and more or less inconclusive, any conclusions which may be drawn must always be open to criticism. A study of the data accumulated, however, brings to light certain very interesting features of the general trend of the experimental results, and furthermore certain facts have been ascertained which have an important bearing on the use of thermal death-point tests in the identification of bacterial species.

Neither of the previously stated hypotheses as to why a few individuals in all cultures are able to resist conditions which are fatal to the large majority of the bacteria in the culture appears to be sustained by the experimental data. Experiment 195, in which we attempted to produce by the survival of the fittest a race of especially resistant organisms, demonstrated a diametrically opposite result, while Experiment 197, in which we tried to make a race of non-sporulating bacteria simulate spore formation by placing them under conditions unfavorable to their development, also failed in its purpose. It is

quite possible, however, that more conclusive results might have been obtained if the experiments had been continued over longer periods of time. The general tendency of both experiments has been toward the establishment of a race in which the more resistant individuals would be entirely eliminated. This is not very clearly shown in the tables, and if the bacteria-temperature curves for each of the individual



LOGARITHMIC CURVES OF TEMPERATURE RESISTANCE, EXPERIMENT 195

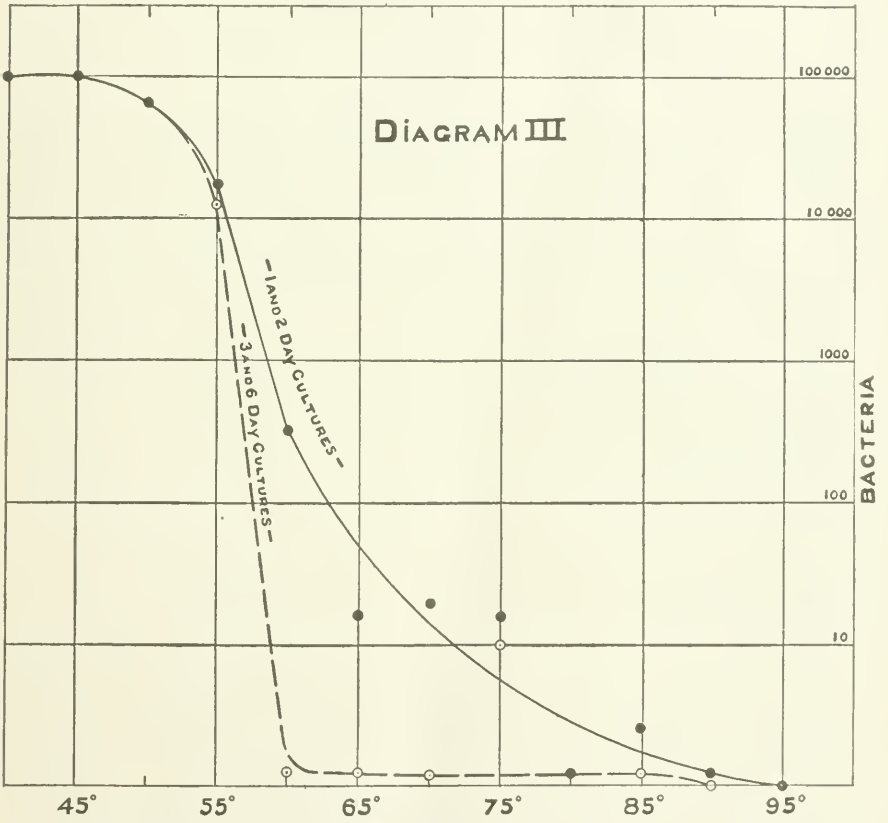
determinations be plotted, this tendency is partially obscured by the erratic behavior of some of the cultures. If, however, the results obtained in the first portion of each experiment are averaged and the curves plotted, omitting values which are obviously abnormal, and the results obtained during the latter portions of the experiments be similarly treated, this tendency toward a culture composed of individuals of more uniform resistance is demonstrated. In Diagram II

three curves of temperature resistance are plotted using the results obtained in Experiment 195, one of these curves being that for the original culture, *i. e.*, the first generation, the second being the average curve for the second, third, and fourth generations, and the third curve being the average for the last five generations. The points used in drawing the curves for the first generation are quite irregularly placed, and it has been impossible to draw a true curve through them. The line as drawn probably represents the true temperature resistance of the original culture. This curve breaks sharply at 50°, and descends in a long, gradual sweep to absolute zero at 95°. The average curve for the second, third, and fourth generations breaks at 50°, the drop being much more rapid than in the first curve and the zero point being reached at 85°. The curve for the last five generations is similar to this second curve, but differs from it in that the decline is somewhat more marked after the break at 50° and that the zero point is reached at 75°. The great uniformity of the cultures included in these last two curves is shown by the position of the various points with reference to the curves. The tendency of the experiment, as indicated by these curves, has been toward the elimination of the majority of the bacteria surviving temperatures above 55° and toward the ultimate production of a culture whose majority thermal death-point is about 50° and whose absolute thermal death-point is apparently between 50° and 60°. The difficulty in eliminating the few resisting individuals is shown by the horizontal approach of the last two curves before they dip to the zero point.

Plotting similar curves for Experiment 197, we find that a similar conclusion is indicated. In Diagram III two curves are shown, one being obtained by averaging the results from the one and two-day cultures, and the other by averaging the results from the three and six-day cultures. The first curve breaks sharply at 55° and descends in a long, gradual sweep to absolute zero at 95°, while the points by which the curve was drawn are somewhat irregularly placed in the higher temperatures, as was the case for the original culture (Diagram I, first generation). The second curve breaks sharply at 55° and descends almost to zero at 60°, then follows a horizontal line to 85°, dropping to absolute zero at 90°. In this second curve all the points fall in line except the one at 75°. The tendency to eliminate all but a few specially resistant bacteria and toward the ultimate production of a race of bacteria whose majority and absolute thermal

death-point shall be practically the same is again illustrated in these curves.

On four of the days on which thermal death-point tests were made in Experiment 195, duplicate tests were made on two cultures from the same stock of the preceding day, one of the cultures tested having originated from the organisms which had survived a temperature just



LOGARITHMIC CURVES OF TEMPERATURE RESISTANCE, EXPERIMENT 197

above the normal thermal death-point, while the other culture tested had originated from the organisms which had survived a temperature just below the absolute thermal death-point. A careful comparison of the thermal death-point tests with these two classes of cultures fails to reveal any difference in their behavior, either when studied individually or when the two series of results are averaged.

The most important facts noted in the investigation are the resistance

of some of the organisms to temperatures considerably higher than have been previously recorded for this species under similar conditions, and the practical uniformity in the temperature at which the larger number of the bacteria have been destroyed as contrasted with the variation in the actual thermal death-point. In the procedure generally recommended for the determination of the presence or absence of spores, broth cultures of the species under examination are immersed in a water bath at a temperature of 80° C. for five minutes, and if any organisms are able to develop in the broth after such treatment the species is presumed to be included among the spore-bearing types. During the eighteen different thermal death-point tests made a few organisms resisted temperatures of 80° C. or over for five-minute periods in over 55 per cent. of the determinations. Relying on the thermal death-point tests alone, we must include the culture used for these experiments among the spore-forming bacteria, although careful morphological examination has repeatedly failed to show any evidence of true spores. The interpretation of what constitutes spore formation would appear to require careful study before we make use of that factor in a natural classification of bacteria. In contrast to the wide variation in the absolute thermal death-point of the various cultures is the practical uniformity in the temperature at which the majority of the bacteria in all cultures were destroyed. The temperature at which final sterilization occurred varied from 60° to 95° in the eighteen different tests, while the death-point for the majority of the bacteria lay between 50° and 55° in the fourteen tests made in Experiment 195, and between 55° and 60° in the four tests made in Experiment 197 — a total range of only 10° as compared with a range of about 35° in the absolute death-point. The fairly constant results obtained in the determinations of this temperature, *i. e.*, the normal thermal death-point, would lead to the belief that its application in the identification of bacterial species would be of more value than is the determination of the absolute thermal death-point.

BOOK REVIEWS

Methods of Organic Analysis[1]

That a substantial and somewhat diversified course of laboratory practice in the methods of organic analysis should form part of the training of every professional chemist is now a generally recognized fact. The successful conduct of a large and increasing proportion of our chemical industries, as well as the protection of the consumer, demands all the aid which a skillful application of these methods is able to bring.

Professor Sherman's book, written from the viewpoint of a very competent food analyst, contains the well-ordered material for such a course of instruction. In the words of its author, "Its purpose is to give a connected introductory training in organic analysis, especially as applied to plant and animal substances and their manufactured products."

The opening chapters contain full working directions for the leading methods of ultimate analysis, except for those employing the combustion furnace. Chapters III and IV, on aldehydes and alcohols, deal chiefly with ethyl, methyl, and amyl alcohols, glycerine, and formic aldehyde. Chapters V, VI, and VII are devoted to the carbohydrates, treating, respectively: general qualitative and quantitative methods, especially those based on the use of the polariscope and copper reduction; applications of sugar analysis; the determination of starch, and the separation of carbohydrates in cereal products. The leading topics in Chapter VIII, on acids, are acetic acid, acetates, and vinegar. The standard methods for the examination of the oils, fats, waxes, butter, soaps, and lubricants are well described in Chapters IX to XII. Chapters XIII and XIV are devoted to proteids and the analysis of cereal products, and the determinations of milk analysis.

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[1] Methods of Organic Analysis. By Henry C. Sherman. New York: Macmillan. xii + 245 pp., 8vo. Cloth, $1.75.

The descriptions of processes are everywhere accompanied by concise expositions of fundamental facts, principles, and applications. The addition of cuts would in some instances be an advantage to the beginner, but the manner of presentation is so clear and orderly that their absence is not felt as a serious defect.

Although written primarily for the use of college students, the critical comment on processes and on the interpretation of results is so sound and discriminating, and the bibliographical references to the important recent literature of each topic are so complete and well arranged, that the book will repay examination by any analyst. It is an undoubtedly valuable contribution to our analytical literature.

S. P. Mulliken.

Experimental Electro–Chemistry[1]

This book is intended for use in the lecture room and the laboratory. After a brief historical introduction the theory of electrolytic dissociation is explained from an experimental standpoint. The chapter following is devoted largely to descriptions of some experiments of the author's on "electrolytic induction," which do not seem of sufficient interest or importance to the student to warrant being given at such length. Faraday's Law and voltameters are next discussed. In the chapter on energy required in electrolysis, Thomson's Rule is given and explained by some examples; the name, however, is suppressed, and its limitations are not mentioned. In the same chapter a little is said about electro-analysis. The following five chapters deal with commercially important electro-chemical processes for manufacturing chemical compounds (omitting the refining of metals), with directions for carrying them out as laboratory experiments. The author gives long lists of various points to be noted in these experiments, but neglects to point out the importance of computing efficiencies from the data obtained. In a work of this kind it also seems an omission to give the student no idea of the cost of electrical energy. The chapter on the electric furnace and furnace products is too brief to give any idea of the importance of this branch of the subject, and the preparation of organic compounds is

[1] Experimental Electro-Chemistry. By N. Monroe Hopkins. New York: Van Nostrand, 1905. 14 + 284 pp., 131 il.

also very briefly treated. In the chapter on the primary cell Ostwald's experiment illustrating "chemical action at a distance" is clearly and correctly explained; but the same cannot be said of the explanation of the reason why pure zinc does not dissolve readily in acids, for the impression given here is that the phenomenon of "overpressure" is related to the electrolytic solution pressure of the metal in question. The chapter on secondary batteries is confined to lead accumulators. In the chapter on electricity from carbon, the Edison and Jacques cells are described. Contrary to a statement in this connection, in the case of the last mentioned cell, at least, the current is not of thermo-electric origin. In the final chapter some electro-chemical apparatus, such as conductivity cells, are described.

There is a chronologically arranged bibliography at the end of the book. The impression left on the reader after perusing this work is not improved by the misspelling of certain well-known names, such as Becquerel, Seebeck, and Borchers.

Although this work has certain defects which are more or less necessarily inherent in any book which attempts to treat so large a subject in a limited space, the style is such as to hold the attention, and the interest in the subject is increased by the historical treatment adopted.

M. DeK. Thompson, Jr.

American Institute of Electrical Engineers[1]

We are in receipt of two volumes, bound edition, of the *Transactions of the American Institute of Electrical Engineers*. Volume XXII covers the period from July to December, 1903, and is devoted largely to the proceedings of the twentieth general meeting at Niagara Falls, June 29 to July 3, 1903. The principal subjects discussed are electric railways, power transmission, engineering education, electro-hydraulics, electric traction, electro-chemistry, and central stations. Volume XXIII covers the year from January to December, 1904, and includes the proceedings of the annual meeting at New York in May, 1904, and the annual convention in St. Louis, September 14, 1904. In this volume

[1] American Institute of Electrical Engineers, Transactions, XXII and XXIII. New York, 1904–05.

will be found papers and discussions on alternating current railway motors, high pressure lines, high pressure transmission, alternating current generators, high tension transmission, transmission of intelligence, heavy electric traction, and the problem of the distance to which power can be transmitted economically.

The particular method of publication employed by the American Institute of Electrical Engineers certainly has advantages, but it also has its disadvantages. While it adds greatly to the ease of reading in bound volumes to have the papers and discussions on the same subject printed continuously, although written by various authors and delivered at different places and different meetings; on the other hand there has been danger of confusion in matters of reference. For example, a person who had read in the monthly edition Mershon's paper on the "Maximum Distance to Which Power Can Be Economically Transmitted," and wished to make a bibliographical reference to this, would put it as appearing in the *Transactions of the American Institute of Electrical Engineers*, Volume XXI, pages 871–892; but if again wishing to refer to the article, and looking in the bound volumes, he would find it, not in Volume XXI at all, but in Volume XXIII, pages 759–781. The confusion which is caused by this arrangement has been partly obviated, however, by a new departure on the part of the Institute. The monthly transactions are now published, beginning with the January number for 1905, under the title of "Proceedings," while the title "Transactions" is retained for the annual bound volumes. The "Proceedings" begin with Volume XXIV, No. 1, and the last number of the monthly issue of the "Transactions" is Volume XXI, No. 10; so there will be no Volumes XXII and XXIII of the monthly publication.

Asbestos and the Asbestos Industry[1]

An idea of the rapid growth of the asbestos industry in Quebec may be gained from the fourfold increase in production during the last decade. It seems fitting, therefore, that the story of progress and existing conditions should be told at the present time.

[1] Franz Cirkel: Asbestos, Its Occurrence, Exploitation, and Uses. Mines Branch, Dept. of the Interior, Ottawa, 1905. 169 pp., 19 pl., 38 il., map.

The author makes eight main divisions of the subject:—

History, Qualities of Asbestos, Geological Distribution and Characteristics of the Deposits.
Mining of Asbestos.
Dressing of Asbestos for the Market.
Costs of Extraction, Market and Price Statistics, and Status of the Industry.
Asbestos Mines and Prospects.
Asbestos in Foreign Countries.
Commercial Application of Asbestos.
Abstract of Mining Laws of Quebec, and Bibliography.

Practically all of the asbestos of Quebec is chrysotile and occurs in serpentine rocks within a comparatively small area. Owing to the nature of the deposits, the mining is almost entirely surface work in open pits, using quarrying methods. In the dressing, the larger pieces of asbestos are freed from waste rock by hand picking and cobbing, while the balance is given a mechanical treatment. The preliminary step is to crush the material by ordinary rock breakers, followed by rolls and pulverizers. This leaves the rock granular and the asbestos in fiberized form, both intimately mixed. The final step is to separate the two by the use of screens and suction fans. The evolution of the scheme of dressing is comparatively recent; it has contributed largely to the progress of the industry. Thus, material which was thrown upon the dump a few years ago is now being worked over in the mills at a profit. The individual mines of Quebec are described in detail and the chief asbestos deposits of the world are well covered. An important factor in the development of the industry is the variety of commercial applications of asbestos, which are constantly on the increase. The author describes these fully.

To one who is interested in asbestos this report is to be recommended as containing very complete information thoroughly up to date.

C. E. L.

Mica and the Mica Industry[1]

The aim of the author is to "furnish an exhaustive compilation of data and general information in the form of a concise report."

He deals first with the physical and chemical properties and

[1] Franz Cirkel: Mica, Its Occurrence, Exploitation, and Uses. Mines Branch, Dept. of the Interior, Ottawa, 1905. 148 pp., 38 il., map.

geographical distribution of the micas in general, and then considers the occurrence of muscovite and phlogopite, with special reference to the Canadian deposits. The mining operation and preparation of mica are described, and the mines of Quebec and Ontario are taken up in detail. Information is given regarding the present status of the Canadian mica industry and the commercial applications of the product. One chapter is devoted to mica in foreign countries. An appendix contains the mining laws of Ontario and Quebec.

The aim of the author appears to have been reached. The book is, in truth, a concise report. The commercial side of the industry has been particularly well covered.

C. E. L.

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS

Vol. XIX JUNE, 1906 No. 2

PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-FOURTH YEAR, 1905-1906

Boston, March 8, 1906.

The 620th regular meeting of the Society of Arts was held in Room 22, Walker Building, Institute of Technology, on Thursday evening, March 8, 1906, at eight o'clock. Seventy-eight persons were present. Dr. William H. Walker presided.

The minutes of the previous meeting were read and approved. There being no routine business, the chairman presented the speaker of the evening, Mr. Henry G. Kittredge, editor of the *Textile American*, who addressed the Society on the subject of "Shoddy, or the History of a Woolen Rag." [1]

Mr. Kittredge gave an historical account of the development of the shoddy industry, and described what is meant by shoddy and its method of manufacture from rags. He showed its economic value as a substitute for new wool, stating that not sufficient wool is grown

[1] Below, pp. 65

to meet the demands for woolen fabrics. The manufacture of mungo was also briefly described.

The lecture was illustrated by stereopticon views showing the process of manufacture and the machinery employed.

The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

Boston, March 22, 1906.

The 621st meeting of the Society of Arts was held in Room 22, Walker Building, Massachusetts Institute of Technology, on March 22, 1906, at eight o'clock. Professor Augustus H. Gill presided, and 135 persons were present. The minutes of the previous meeting were read and approved.

The chairman then introduced Professor William H. Walker, who addressed the Society on "The Chemistry of Cellulose as Applied to Textile Fibers, Mercerized Cotton, Artificial Silk, and Horse Hair." The speaker described the work which led to the application of the process to mercerization on a practical scale, and also outlined the chemistry of cellulose. The difference between nitro-cellulose and the derivative substances was shown by experiment, as was also some of the physical properties of the cellulose derivatives. The use of artificial silk and artificial horse hair in the manufacture of fabrics, laces, hats, etc., was described and demonstrated by a very complete collection of samples. The machinery used in the manufacture of these products was shown by means of lantern slides.

Some discussion followed, and the chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

Boston, April 12, 1906.

The 622d regular meeting of the Society of Arts was held in Room 22, Walker Building, Massachusetts Institute of Technology, on Thursday evening, April 12, 1906, at eight o'clock. Mr. George W. Blodgett, chairman of the Executive Committee, presided. Attendance, seventy-eight.

The minutes of the previous meeting were read and approved. Mr. Joseph W. Phelan was elected an Associate Member of the Society.

The speaker of the evening was Mr. Ernest Harold Baynes, who addressed the Society on "The American Bison, Our Grandest Native Animal." Mr. Baynes gave an idea of the numbers and range of this animal in the past and the methods which were adopted by the whites and Indians for its destruction, and which have resulted in its almost complete extermination. He said that the number of these animals existing is but a few hundreds, and these are located in two or three groups, the largest of which is at Corbin Park in New Hampshire. The methods for assisting its propagation were described, and a strong appeal for its preservation by national aid and through private individuals was made by the speaker.

The lecture was illustrated by a number of colored lantern slides showing the characteristics of the animal at different stages in its development. An especially interesting series was one which showed a couple of buffalo calves which had been broken to harness by the speaker. The chairman extended the thanks of the Society to the speaker, and the meeting adjourned.

Boston, April 26, 1906.

The 623d regular meeting of the Society of Arts was held in Room 22, Walker Building, Institute of Technology, on Thursday evening, April 26, 1906, at eight o'clock. Mr. James P. Munroe presided. Fifty-five persons were present.

There being no routine business the chairman introduced Mr. H. F. J. Porter, of New York, who addressed the Society on "The Rationale of the Industrial Betterment Movement."

Mr. Porter said that the move to secure better surroundings for the working people by improving the sanitary conditions and supplying recreation rooms, gymnasia, etc., is not based entirely upon charity, but in most instances is a good business investment for the employer because of the increased efficiency of the employees.

He described the improvements instituted by several companies, notably the National Cash Register Company of Dayton, Ohio, and

showed by a series of pictures the conditions prevailing in several works before and after the industrial betterment movement had gone into effect.

After some discussion on the subject the chairman expressed the thanks of the Society to the speaker for his excellent talk, and the meeting adjourned.

SAMUEL C. PRESCOTT, *Secretary.*

SHODDY, OR THE HISTORY OF A WOOLEN RAG

By HENRY G. KITTREDGE

Read March 8, 1906

NOTHING marks more completely the industrial progress and efficiency of a nation and people than the utilization of products that have been thrown aside in the manufacture of other products, that can be turned to a useful purpose in meeting the desires or necessities of man.

Nearly all great municipalities have systems for collecting rubbish within their precincts with one of the objects, however secondary it may be, of turning it to some commercial account. For example, the rubbish found in the streets of Boston is collected in carts by scavengers and carried to a general refuse station, where it is sorted on movable tables, by Italians, it may be. At the refuse station, each sorter has his particular kind of waste to pick out as it moves in front of him, to be thrown into a pile or bin by his side, and afterwards pressed into bales. The clean, high grade paper sorts are used in the manufacture of paper again, and the lower grades are used in making different qualities of paper cardboards. This is the shoddy of the paper manufacturer. Ropes and burlaps are used to make yarn for cheap burlaps. We have here another kind of shoddy. Old boots and shoes find their way to the glue shop. Tin cans are thrown into a furnace and the solder is saved for further use as solder, while the melted tin is cast into molds for window sash weights. Old iron hoops, etc., are remelted into scrap iron ingots. Bottles are sold at so much a barrel and again made use of for various purposes. Cotton rags are picked out for paper stock, while the woolen rags are sold to junk dealers, who sort them over for the shoddy manufacturer. Thus it will be seen that scarcely anything is allowed to go to absolute waste, and never a word is raised against this practice in industrial economy, except as it may relate to woolen rags for their subsequent conversion into a wool substitute. We find in this municipal practice of collecting rubbish and assorting it into kinds one of the beginnings of the wool shoddy industry.

The word shoddy is, without doubt, a modern factory term, and this view of it is taken by the Century Dictionary, which regards it as "a dialectic form (diminutive or extension) of dialect 'shode,' literally 'shedding,' separation, shoddy being originally made of flue or fluff 'shed' or thrown off in the process of weaving, rejected threads, etc."

A cognate word to shoddy is mungo, a term, however, peculiar to the parlance of English rather than of American mills. The Century Dictionary gives an alleged but unverified etymology of this word as coming from "mung," "mong," "mang," meaning a mixture, as in

FIG. 1. — INTERIOR OF A REFUSE STATION
Sorting street rubbish on a movable table

mangcorn. The woolen trade, however, gives it an outlandish derivation, as a corruption of the expression "must go," from a circumstance which should be alluded to especially, as it has a traditional relationship to the word "shoddy," and is indelibly associated with the origin of the shoddy industry, although entirely confined to Yorkshire (England) patois. It is related, upon very uncertain authority, that at the time this shredded or picked up stuff was invented a dealer possessed a quantity of it, and some doubt was expressed as to its salability, when he declared that "it mun go," meaning that it must go. There are variations of this story.

The inventor or originator of shoddy as a material to work with wool for spinning is unknown; and whoever may receive the credit holds the distinction largely upon the acquiescence of those who cannot show evidence to the contrary. Samuel Jubb says that the presumption is in favor of Benjamin Law as the person who first produced it, at Batley, in 1813 or prior thereto; but it appears that several persons began the making of shoddy at about this time.

There is a claim for Brighouse as having had in operation rag machines prior to any in Batley, but in qualification of this claim it is said that these machines were for picking thrums, hard worsted waste, and the like, and not for producing rag shoddy.

It has been intimated at times that George Parr, an early manufacturer of mungo, was entitled to the credit of appropriating rag wool to the manufacture of woolen cloth. This intimation, however, must be regarded as more or less gratuitous, as it has been disowned by his descendants even as late as 1880, when his son Benjamin is reported to have said that he never knew of any rival claim to that of Mr. Law having been set up by his father of being the first to manufacture shoddy cloth.

FIG. 2. — SHODDY MANUFACTURING DISTRICT OF ENGLAND

Solid black dots show the principal centres of manufacture of shoddy

The rag grinding machine in the early part of the nineteenth century was a most primitive affair. We are told that the first one for pulling rags to pieces or converting them into fibres was made by Joseph Gibson, of Cleckheaton, at the suggestion of Joseph Jubb, a leading business man of Batley, who had conceived such a machine from one he had seen running at Brighouse. The next machine was constructed by a Mr. Archer, of Ossett — a name that afterwards became identified with the early history of the industry in the United States.

As soon as it became known that woolen fabrics for clothing were being made with an admixture of shoddy with pure wool and sold in the market as consisting of pure wool, denunciations of the most pronounced kind were hurled against their manufacture. The London *Times* and other newspapers in the kingdom anathematized this species of wool manufacture as militating against the morals and health of the people. No doubt the shoddy cloth of that time was miserable stuff and deserved all the bad epithets which it received, as the material out of which it was then made was quite different from what it is today.

Up to 1834 the only class of stock that was available for converting into shoddy was technically known as "softs," as flannels, stockings, etc., or such as was knit or loosely woven. All closely woven or felted rags had been cut into flocks or thrown away as so much rubbish and allowed to rot till they became fit for manure. Until then the rag-picker had not been mechanically improved so as to permit it to shred this kind of closely textured material. By this time, however, the machine had been so improved in structural details as to enable it to pick into a fibrous condition hard felted cloth, as broadcloth, kerseys, etc. This suggested to George Parr the commercial advantage of utilizing this stock in the same way as was being done with stockings, etc., for preparing it for manufacture into goods. In the carrying out of this idea, Mr. Parr is credited with being the inventor of mungo, which the prepared material was christened, from the incident already alluded to, which, however, may not have occurred till later. The advent of mungo as a coördinate material with rag wool made from soft stock established an important era in the history of the woolen industry in England, and soon led to significant events in the United States that gave to our manufacturers an intimacy with the utility of this stuff for mixing with wool. The material obtained from soft rags was totally unsuitable for fabrics as pilot cloth, beavers, or any kind of heavily felted or face-finished goods; hence its opportunities for usefulness were limited. That obtained from hard rags was finer fibred and better adapted for this class of goods, and for this reason was of more beneficial consequences to the woolen trade.

It has already been observed that one of the first rag pulling or shoddy machines built was made by a Mr. Archer, of Ossett, probably about 1810. In 1831, Richard Ardict, living in the adjoining town of Dewsbury — a friend and neighbor of this Mr. Archer or of the Archer family — believing that the United States offered business opportunities

that were not apparent in England, bought of George Archer, of Ossett, son of the Archer alluded to, a ragpicker, as it was then called, boxed it up, and shipped it for New York as a rice threshing machine, intending to follow it himself on the next vessel; but before the vessel carrying the machine had been fairly on its way the British government was informed of the artifice and attempt to circumvent the act of Parliament prohibiting the export of machinery and tools.

In consequence of this violation of the statute, Mr. Ardict was

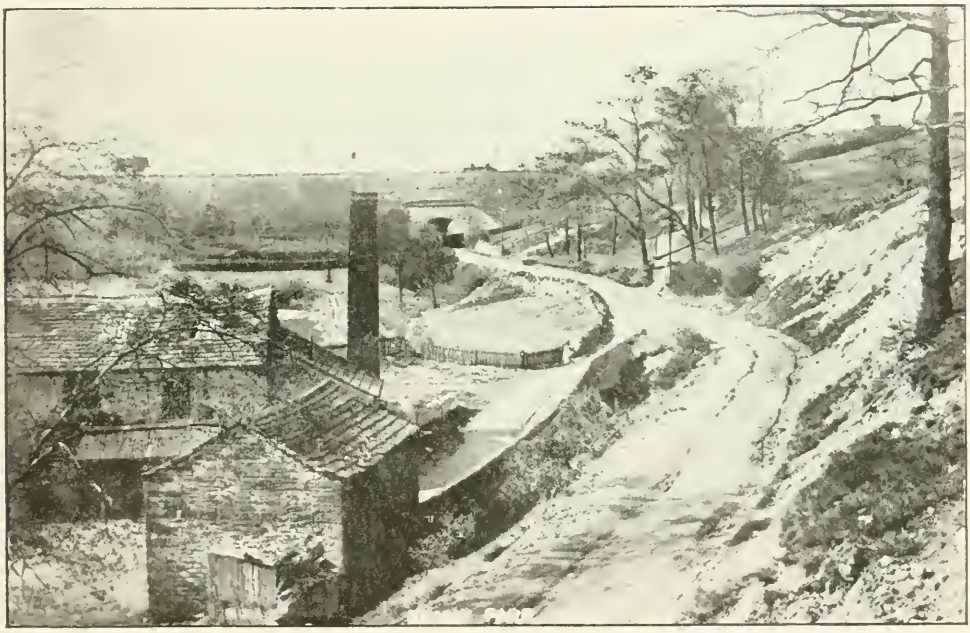


FIG. 3.—GEORGE PARR'S SHODDY MILL, BATLEY, ENGLAND
In operation in 1834, and many years prior thereto

arrested; but after he had been incarcerated for some time he was given his liberty upon the payment of a fine of twenty-five pounds sterling. He had, however, accomplished his purpose in getting his machine out of the country, and immediately sailed for New York, where he found his machine had already arrived safely. He moved it to Marlborough, Ulster County, New York, and there started the first shoddy mill in this country in what was known as the Hepworth Mill. He carried on the business there for many years and then moved the plant to Esopus, New York.

Soon after the departure of Richard Ardict from Yorkshire for the United States, George Archer began to contemplate quite seriously the plan of doing likewise. He completed all necessary arrangements for this purpose and started for New York in 1836, his family following three years after. Profiting by the experience of his friend Ardict, and "knowing a trick worth two of that," instead of exporting a machine contrary to the statutes of the kingdom he simply stored away in his baggage a complete set of drawings for the various machines used for the manufacture of woolen goods, including those for the construction of a ragpicker.

Shortly after Mr. Archer's arrival he formed a copartnership with a Mr. Bailey and a Mr. Ogden, under the firm name of Archer, Bailey and Ogden, and located at Little Falls, New Jersey. Mr. Archer's part of the business was to build the machinery, while his partners looked after the manufacture of shoddy and cloth. This firm continued in business for several years, when Mr. Archer withdrew and moved to Paterson, New Jersey, where he engaged, alone, in the building of shoddy machinery. After being in Paterson for a number of years, he moved to Tuckahoe, New York, from there to Cohoes, New York, and finally settled in Marlborough, New York, where he continued to make shoddy machinery till the time of his death, in 1875, at the age of seventy-two.

In connection with the beginning of the shoddy industry in the United States, as established by Richard Ardict and George Archer, should be mentioned the early enterprise of A. G. Dewey, Quechee, Vermont, the most distinguished of the pioneers in this line of manufacture. Mr. Dewey commenced the manufacture of shoddy and of goods in which this material was used, in 1841, at Quechee, and successfully conducted it to the time of his death in 1886, when it passed into the hands of his sons. The shoddy picker used by Mr. Dewey was an invention of Reuben Daniels, of Woodstock, Vermont. This invention was wholly original with Mr. Daniels, who knew nothing of the machines of Mr. Archer. It is safe to say that his machine was different from the English make, but in what particulars there is nothing in existence by which this can be even partially or moderately determined. He was a large and successful builder of woolen machinery, and his shoddy machines were probably designed from the picker he was then building for working wool, with the cylinder armed on its periphery with hooks of claws. The picker, it is known, reduced the

rags to very small pieces and shreds, which were then run through another machine, called a "grinder," which had a double cylinder with under workers arranged in a long box containing running water, which carried the stock through.

No patent of a ragpicker similar to the kind now in use is on record in the patent office at Washington. There was a patent taken out by O. Griswold in 1837 for a waste picking machine that suggests the possibility of its use for picking rags, though in the specifications no direct reference is made to shoddy by name. A patent was given to J. Bailey in 1849 for a waste picker that might have answered for tearing up rags, and may have been designed for this purpose, as reference is made in the specifications to its adaptability for the manufacture of shoddy.

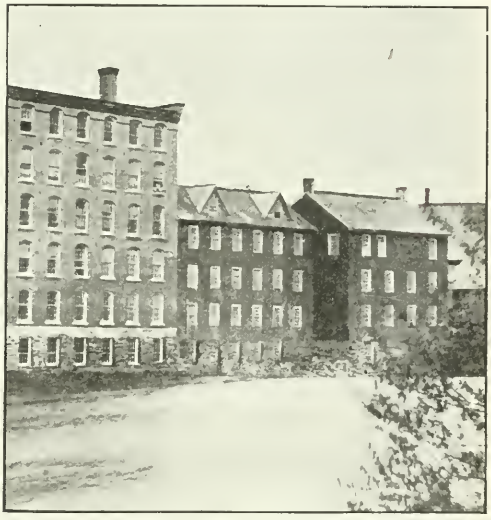


Fig. 4.—Shoddy Mill of A. G. Dewey, Quechee, Vt.

At the right of the new brick building. The oldest shoddy mill in the United States now in existence. Operated since 1841

It was not many years ago when most of the woolen rags that were collected in the United States for manufacture into shoddy were procured from the housewife by the tin peddler and his one horse cart, in return for which he bartered certain household wares, and afterwards disposed of his rags to the rag dealer. In those days rags and other similar household savings were worth something, or at least enough to warrant the exercise of this domestic economy, but now the price received is of scarcely sufficient inducement to pay for the trouble of saving.

The tin peddler has given or is rapidly giving way to the junk collector with his sack or team, whose occupation is largely passing into the hands of those of foreign birth, especially the Russian Jews. This class of people may be seen in the neighborhood of all the large cities in the North, with a sack in the hand or thrown over the shoulder, going from house to house for whatever rags they can obtain, to be afterwards disposed of to the junk dealer.

The junk dealer sorts his various purchases into grades, usually five in number — as old cloth and garments; soft woolens, as knit stuffs, flannels, etc.; satinets and linseys; carpets; and cotton.

The junk dealer's customer is the rag dealer, who sometimes conducts a large business, for which purpose he occupies extensive

FIG. 5. — GROUP OF RAG SORTERS

quarters and employs a large number of employees, made up mostly from the foreign element of our population. The rag dealer goes over his old cloth sorts and makes new sorts of them according to quality and color, or whatever it is desired to obtain to meet the peculiar demands of trade. The old garments are treated likewise after all the linings, etc., have been removed.

New rags, or new clips, as they are called, consisting of tailors'

trimmings or clippings made in the cutting rooms of ready-made clothing houses and elsewhere, are purchased direct by the rag dealers and not through junk dealers.

After the rags have been sorted by the dealer, each kind is baled by itself and securely bound with wire or hoops for transportation.

When the rags are received at the shoddy factory they are again looked over or more carefully sorted to meet more thoroughly the par-

FIG. 6.—RAG SORTING IN A DEALER'S LOFT

ticular wants of customers, more in respect to color than to quality, though the latter may be considered, especially as to whether the rags are old or new, all wool or partly cotton, and, if the latter, thrown aside for the "extract" process. Much depends on the use to which the shoddy is to be put.

There are several kinds of processes through which woolen rags pass into shoddy, dependent on the nature of the rags and what is wanted. If the rags have cotton threads in them they are submitted to the "extract" process.

FIG. 7. — CUTTING ROOM IN A TAILORING SHOP

Excellent sanitary arrangements. Where "new clip" rags are obtained for the nicest class of shoddy

FIG. 8. — A BAKING ROOM FOR CARBONIZING RAGS

Rags are seen on tables. Temperature kept at 200° and above for about eight hours

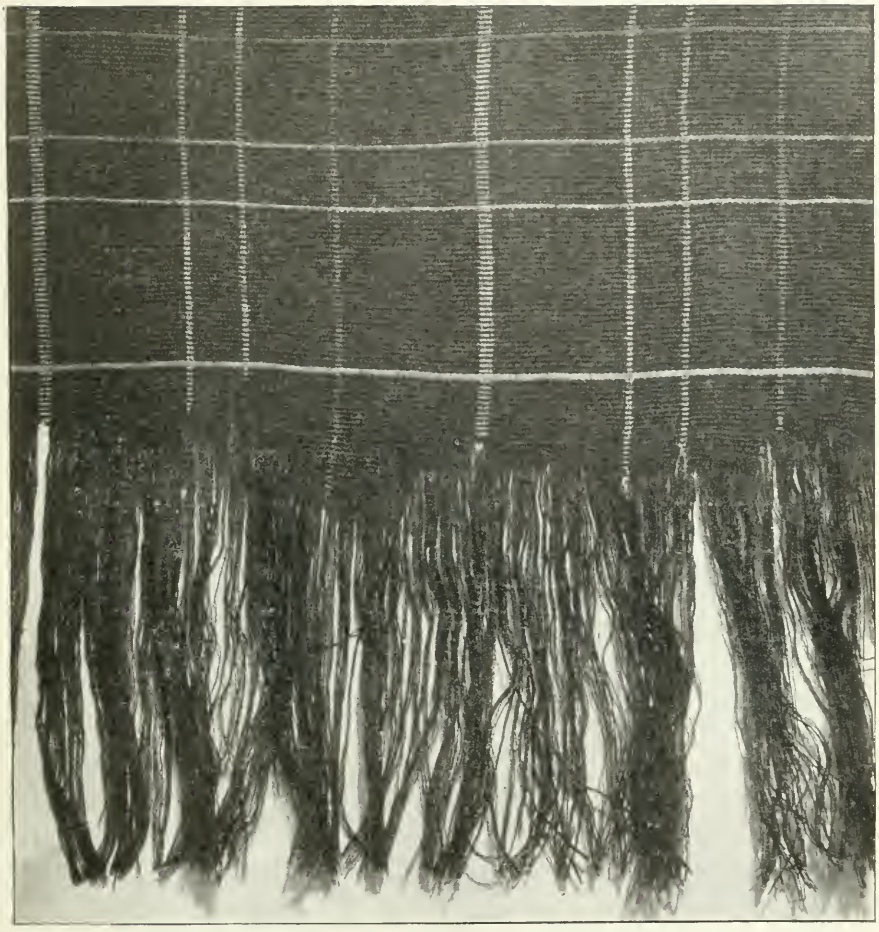


FIG. 9. — PARTLY CARBONIZED CLOTH

The warp of this cloth is wool, the weft cotton. The lower end has been carbonized and the cotton destroyed, leaving the wool intact

The "extract" process is simply a method of eliminating or extracting vegetable matter that may be associated with wool in rags. The process is better called carbonizing by which the vegetable substance, as cotton, is eliminated by acid and heat, which converts the cellulose into hydrocellulose, which is removed by mechanical means.

All methods of drying are practically the same, in that the rags are exposed to a heat of 200 or more degrees for about eight hours. The acid and heat burn the cotton to a powder that is easily shaken out in an ordinary dusting machine.

After the carbonized rags have been dusted they are put into a washing machine and washed with water with some alkalinity to neutralize the acid remaining in the rags. The rags are then redried for the ordinary processes employed in the manufacture of all-wool shoddy.

None of the extract processes came to be employed to any great extent, in the United States, at least, till well after 1870, because of the prejudice against them as injuriously affecting the felting properties

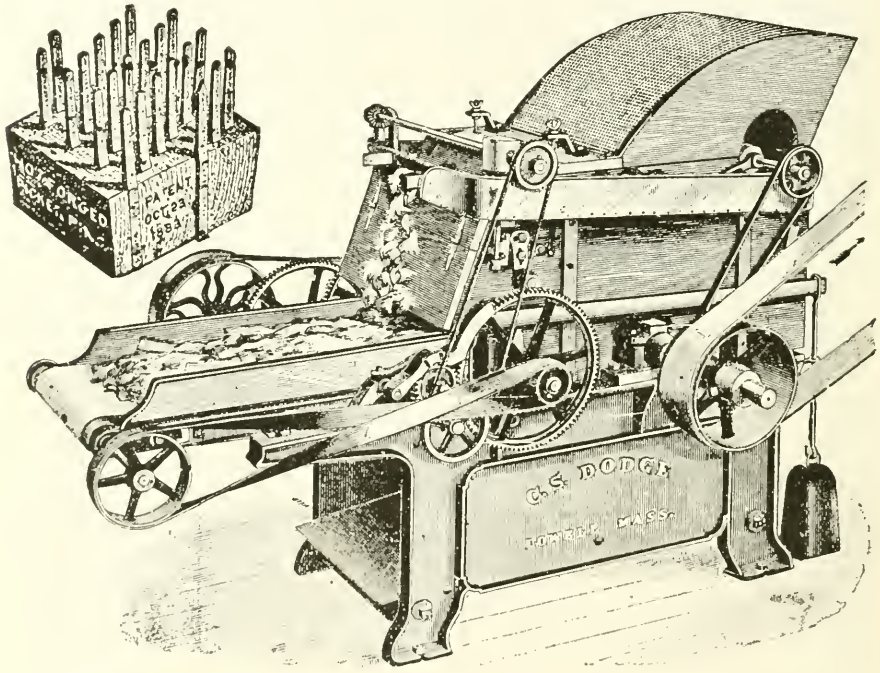


FIG. 10. — A MODERN SHODDY PICKER

Portion of a peripheral wooden lag, magnified, is shown with the picker pins, or teeth, inserted

of the wool fibres, due very largely to the imperfect knowledge of the proper methods that should be pursued in the joint application of acid, heat, and neutralizing alkalies.

The shoddy picker which is employed for manipulating every kind and condition of rags, whether for extract, mungo, or what not, is a very simple and inexpensive piece of mechanism, consisting of a large, heavy cylinder, in the peripheral wooden lags of which are securely driven a large number of closely set straight steel pins or teeth, by which

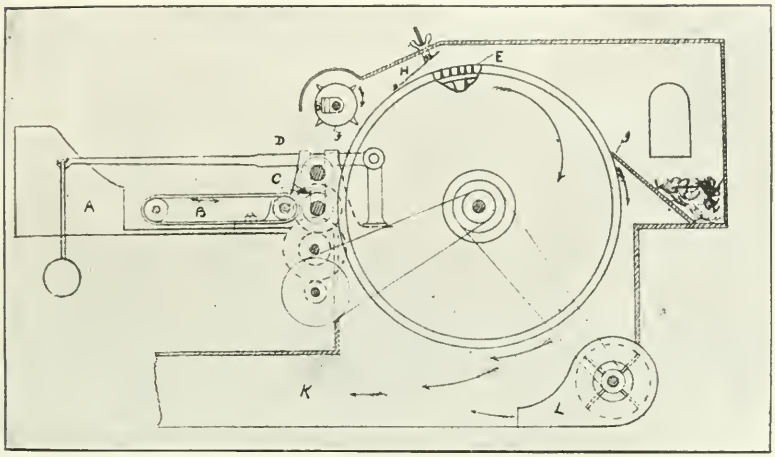


FIG. 11.—SECTIONAL VIEW OF A MODERN RAG PICKING MACHINE
Style used in England

A. Rag box.
B. Movable feed table.
C. Feed rollers.
D. Lever with weight.
E. Main cylinder showing teeth.
F. Bitter.
H. Knife board.
I. Bit board.
K. Flue.
L. Fan.

FIG. 12.—MEN FEEDING TWO SHODDY PICKING MACHINES
Rags are seen on the floor and on the machines

the picking of the stock is effected as they revolve in close contact with two small steel feed rolls that slowly deliver the material to be operated on.

Shoddy is oftentimes used in the manufacture of goods just as it comes from the picker, but when a nice preparation of the stock is required it is passed through a carding machine or an ordinary wool card.

After leaving the picker or the carding machine, as the case may be, the shoddy is packed in bags for transportation to the consumer. When waste yarn or soft, very loosely woven, or knit, goods are converted into shoddy, the picker and the carding machine may be done away with, and the Garnett machine alone employed. This is a comparatively new machine invented by an Englishman by the name of Garnett. It is usually built with three main cylinders, with a large number of smaller cylinders, all provided with steel teeth, working in conjunction with each other so as to tear the stock to pieces and convert it to a fibrous condition ready to be used the same as wool.

Akin to shoddy are flocks or powdered wool made from cut or ground up woolen rags. Rag flocks are first prepared on a machine, which cuts the rags into small pieces or strips in good condition to be fed into the flock cutter. In the manufacture of woolens, flocks are employed for increasing the weight of the goods with a material much less in cost than either wool or shoddy, and in this respect are as much a substitute for wool as shoddy; but instead of being mixed and spun with wool like the latter in the ordinary processes of manufacture, they are incorporated into the fabric after it leaves the loom, during the process of felting or fulling; and so firmly do they become embedded in the texture of the goods that it is impossible or very difficult to dislodge them, and to this extent permits the manufacture of a compact, heavy, and durable cloth at a comparatively small cost.

In the process of shredding rags it is reasonable to suppose that more or less injury will be done to the fibres, but the damage done is very much less than may be thought.

However great the consumption of shoddy, flocks, etc., may be, it does not begin to meet the deficiency in the supply of wool, which has to be supplemented quite as much, if not more, by cotton. If I should place the world's consumption of shoddy at 300,000,000 pounds — an extreme amount, probably — it would be nearly one-fourth the consumption of clean wool. The consumption of shoddy in the United States

may be taken at about 80,000,000 pounds, or little more than one-half that in Great Britain. In our woolen mills alone — not including those for worsteds, carpets, felts, and knit goods — at the time the 1900 census was taken, for the manufacture of cloths, overcoatings, tweeds, flannels, cassimeres, satinets, etc., there were used about 120,000,000 pounds of clean wool and other animal fibres, and about 67,000,000 pounds of shoddy, or altogether 187,000,000 pounds, nearly 36 per cent. of which was shoddy. Our woolen goods, therefore, as a whole, carried a good

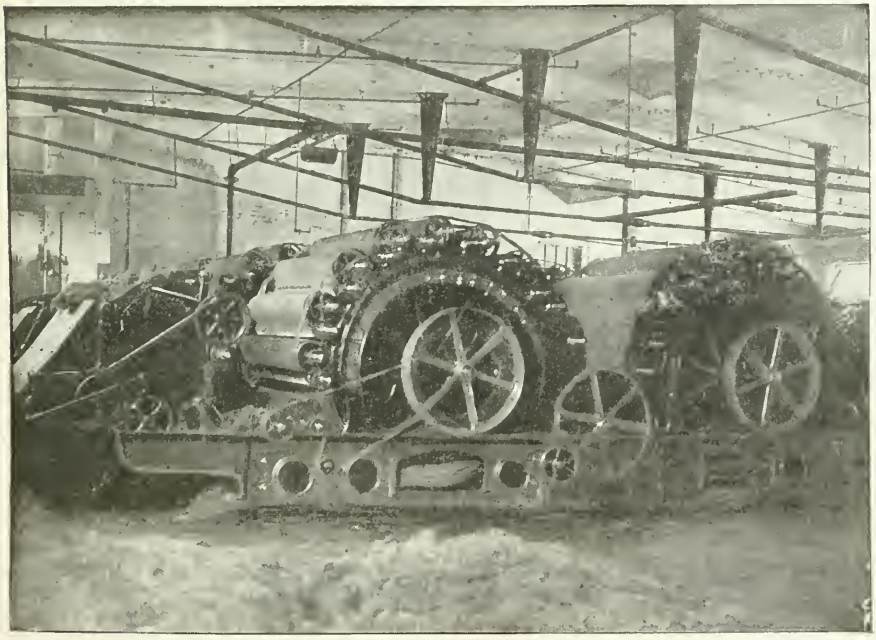


FIG. 13. — A DOUBLE CARDING MACHINE
Used when a nice preparation of shoddy is required

proportion of shoddy at that time, with probably little change since. In addition to this amount might be added about 60,000,000 pounds of cotton, showing still more the immense dependence of the woolen industry upon other materials from the animal and vegetable kingdoms than pure wool; and this dependence is not one of choice, but of necessity.

There exists among a great many people a strong and unreasonable prejudice against shoddy as a material in the manufacture of woolen goods. As now made, especially that which has gone through the

extracting or carbonizing process to which most rags are subjected, nothing can be much less deleterious to bodily health. The acid, heat, washing, etc., to which woolen rags are exposed are more than sufficient to kill every germ of disease and to leave the material in a condition less to be apprehended for infectious distempers than pure wool. No matter whence woolen rags may come, before they are converted into shoddy they are made absolutely pure by the extracting or carbonizing treatment. The rags gathered from the scums of communities are made as unsullied as those obtained from the most immaculate households before they are permitted to be used for shoddy. There is much more to be feared from the handling of cotton rags that are collected from all the foul places of the world, many of which are fouler than

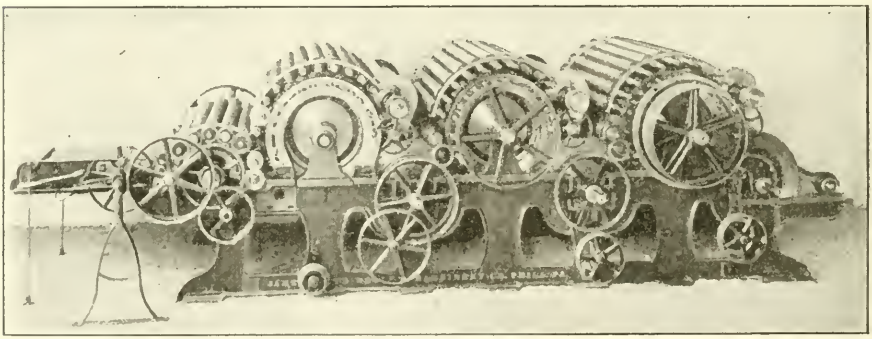


FIG. 14.—A GARNETT MACHINE

For converting yarn, or soft, loosely woven, or knitted goods into shoddy

the foulest whence are obtained woolen rags. Yet these cotton rags are not considered unfit to go into the manufacture of the finest paper for a *de luxe* edition of some choice book, and in this state of existence are little thought of as containing anything detrimental to human health, as they do not. But they are no cleaner or freer from disease germs than the wool shoddy that now goes into the cloth that is made up into garments for our wear. In both instances the chemical treatment to which the rags are submitted is sufficient to kill every vestige of disease that may be present from any cause. The only thing that can be said against shoddy conformable to the fact is that it has a short and perhaps defective fibre, and consequently does not make a high grade cloth. But this objection may be made against pure or unmanufactured wool, much of which has no longer fibre and makes no more desirable cloth other than is secured in a possibly better physical condition of fibre.

The danger of disease from woolen rags is no greater, if as great, than from some classes of wool. In this respect, woolen rags have never been legislated against by commercial bodies and governments as some kinds of wool have been. Nothing like the terrible disease

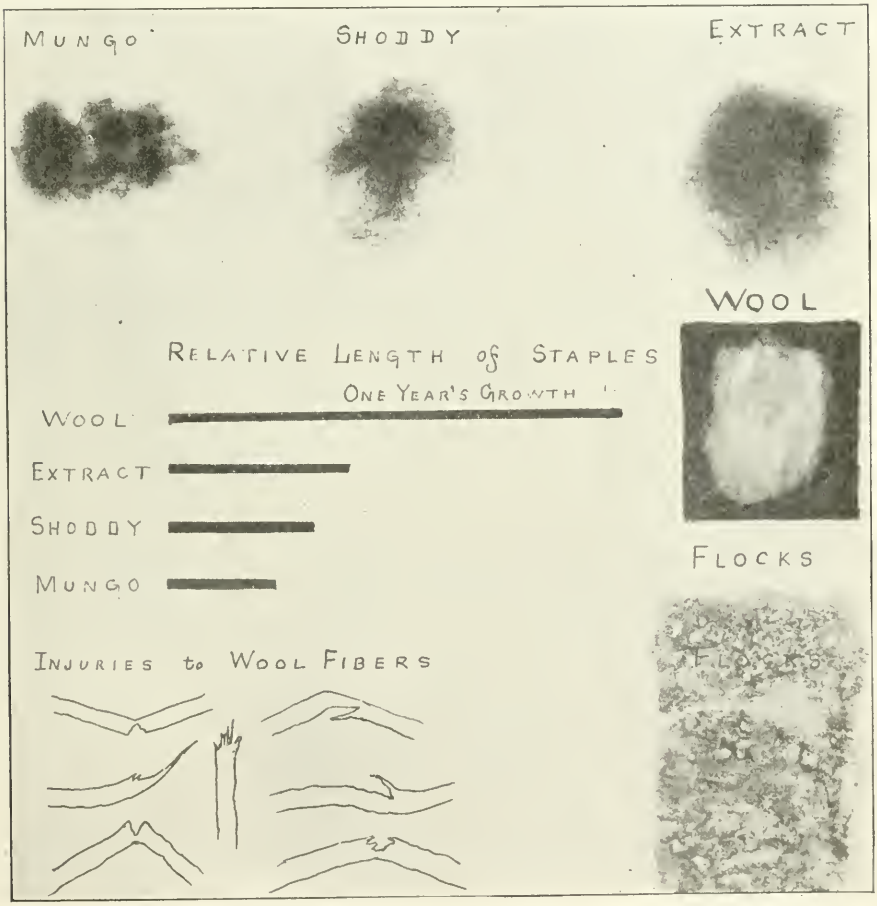


FIG. 15. — PHOTOGRAPHS OF MUNGO, SHODDY, EXTRACT, AND WOOL (CALIFORNIA FALL CLIP, FIVE MONTHS' GROWTH), REDUCED ABOUT ONE-QUARTER

Injured fibres magnified. The injuries done to the fibres are exaggerated, and represent only extreme instances

of anthrax that comes from contact with certain wools and hairs is derived from the handling of woolen rags.

Shoddy is a legitimate article for use in the manufacture of wool, as thoroughly so as the fibre in its original condition from the animal's

back, and is no more a sham or imposture than the real article for which it is substituted; not a particle more than the silver plating on spoons and forks in imitation of sterling silver.

Shoddy is one of the greatest blessings that has been vouchsafed to the wool manufacturing industry. It contributes 300,000,000 pounds of wool fibre every year toward keeping the industry within its legitimate realm, and that much free from dependence on cotton, and it supplies a material for serviceable and well appearing cloth that can be manufactured at a comparatively low cost for the great masses of the people.

Instead of being cursed it should be eulogized.

TECHNICAL CHEMISTRY IN TECHNICAL SCHOOLS

By HENRY P. TALBOT

The position which applied science, as distinct from pure science, occupies in the curriculum of a technical school is often exaggerated in the thoughts of those whose interest may be, from one or another cause, drawn to such institutions. The primary purpose of these schools is to educate their students with direct reference to their usefulness as technicians, and it would seem quite logical that the dominant ideas throughout the teaching of the sciences should be those which relate to their applications to the useful arts, and that, as a consequence, a commercial spirit might well invade the work of the lecture room and laboratory. Indeed, this conception seems occasionally to prevail even in the minds of those no farther removed than the teachers of science in our colleges, for it is not an unknown experience to interview a would-be student who comes with a message from a fellow-instructor in the more academic field which indicates with rather disturbing clearness that he, too, has assumed that the technical school aims to train rather than educate its students. It is not strange, then, that nearly every fortnight brings requests from individuals who have little to guide them beyond their preconceived notions of a technical school, for the opportunity which they believe to be offered to be equipped in the course of a few weeks, or even a few days, for life work as a chemist, frequently in some highly specialized field, and the same thing is doubtless true of other sciences.

It may not, then, be untimely to indicate the extent to which an effort may be made, on the one hand, to educate rather than merely to train the student for his life work in his chosen field of science, and on the other hand how, in the case of chemistry at least, most excellent use can be, and is made of the technology of the science, even from the very beginning of the various courses of instruction.

In planning a scheme of instruction in chemistry for students in a technical school, two serious problems must be confronted at the start,

namely, the vastness of the science and the varying capacity, aptitude, and enthusiasm on the part of the students to be taught. One has but to glance through the subdivisions of chemistry in such a publication as the *Chemisches Centralblatt* to realize the utter futility of any attempt to do more than to gain a general notion of the scope of many of the specialized branches; and when it is remembered that no man today can be an efficient chemist who is not also something of a physicist, mathematician, and linguist, it becomes evident that within the limit of four years a scientific education must be mainly confined to those general phases of the science which are common to most or all of its subdivisions.

The chemistry which is taught in the first year in a technical school must usually be presented to a class which is made up of students who do not expect to follow the subject in later years, others who take professional courses in which chemical subjects play a more or less important part, and still others who expect to follow chemistry in some of its branches as a profession. The first of these groups must obtain their entire conception of chemical science from such a course, and the other two must gain from it a foundation upon which to build in subsequent years. The proportion of the student's time which may properly be claimed for the subject is not large, and the instruction to be adequate must be carefully chosen and should be in the hands of teachers of maturity and experience, both on the lecture room and laboratory sides. Such a course is fundamentally one of instruction in the principles of the science. But principles are abstract conceptions, and they are dry and tedious for the man whose interest is not primarily in this particular science unless they are associated with specific facts, and best with facts that have to do with affairs within the student's personal experience, or those which can easily be shown to lie in the path of probable future experience. It is exactly at this point that the mature man of science can call to his assistance his own professional work to great advantage, and this is often the more effective if the illustration is taken from his contact with technical interests; but this does not at all involve an introduction of what may be termed the dollars and cents point of view or any degradation of instruction. The architect, for example, will the more quickly interest himself in the law of constant proportions or the metallurgy of iron if he is led to understand that these matters are vital to the stability of his structural work; the mechanical or civil engineer will grasp the theory of solutions the more

readily if he is able to see that it applies directly to the treatment of boiler waters; and the mining engineer or the chemist will find in the brief account of the solution of some technical problem from the instructor's professional practice an inspiration for extra reading and study.

With the differentiation of courses which usually occurs at the end of the first year in the technical schools, the problem is partially simplified by the elimination of those students for whom chemical instruction ceases at that time. There remain students in such professional courses as mining engineering, sanitary engineering, physics, biology, and geology, beside those in chemistry or chemical engineering.

Analytical chemistry, as the ultimate measure of accomplishment or the means of control of chemical processes, is an essential for all of these groups of students. Here, again, the judicious teacher will include something of technical chemistry to lend vitality to the work. The substances placed in the hands of the student for examination and report will be chosen from the open market in preference to purely artificial mixtures, and the history of the substance will be told when it is issued for analysis, or upon its completion. The methods of analysis chosen will not, however, necessarily be identical with those used in technical laboratories, but will rather be selected because they represent general types of analytical procedure with which every analyst should be acquainted, and the student will be led to regard them as such and to criticise them and his own work intelligently, in the light of reading and study; that is, the effort will be made to develop a thoughtful, self-reliant worker rather than a man with a knowledge of particular methods. On the other hand, technical methods will not be avoided when they also represent desirable types, nor will the instructor fail to emphasize the requirements of the technical laboratory with reference to speed and accuracy; and "rapid methods" will receive due attention if the time at his disposal is reasonably adequate for this as well as the inculcation of habits of accuracy and self-criticism. The latter must, however, receive first consideration, and no greater mistake can be made in the education of a student as an analyst than to overemphasize the acquisition of methods as such, especially many of the technical methods. Every director of a works laboratory will have his own methods adapted to his own line of materials, and the student who has been taught to meet an analytical problem thoughtfully should have no difficulty in quickly learning these, or, if thrown upon his own resources, in devising methods of his own.

It is sometimes contended that the graduate, fresh from the instructional laboratory, when he enters the works laboratory is slow in his work; that he is overcritical, and too little disposed to cut corners when such abridgment is desirable. But it will surely be granted that these are less serious faults than overhaste and heedlessness, and that a course of instruction in which fundamental principles and underlying reasons are associated with the acquisition of analytical technique offers the surest foundation for successful practice. It is such a course that the technical schools should give and, for the most part, are giving.

The applications of chemistry in technical practice may be summoned to the assistance of the instructor in organic chemistry in much the same way that has already been noted in the case of inorganic chemistry, but to a rather less extent. There is little danger that this course will acquire a commercial taint, as it deals largely with the principles underlying the classification and behavior of the vast collection of carbon compounds, the subject being treated essentially from that standpoint.

Much the same statement may be made regarding physical or theoretical chemistry, which deals with the fundamental principles of the science. But here again much may be gained, without incongruity or sacrifice of dignity, by frequently pointing out to the student a concrete technical application of what appears as an abstract principle.

The technical school, then, like the college, should teach science fundamentally from a somewhat abstract standpoint, for the problems of applied science demand for their solution, before all else, a knowledge of principles. Students are all too prone to feel that only those phases of the science the applications of which they can appreciate are worthy of their serious attention — a notion which no institution can afford to foster by giving to such general subjects as inorganic, organic, theoretical, or analytical chemistry a more directly commercial trend than has been outlined above. On the other hand, it is essential that students who are to make the application of chemical science their life work should be afforded opportunities to learn something of the general methods employed and of the practical problems to be met with in that field, and to this end it is necessary to offer separate instruction in what is usually designated as "industrial chemistry," in the course of which these matters are frankly treated. The scope of a proper scheme of instruction in industrial chemistry may well be a theme for much discussion, and the final word may not soon be said.

It is obvious that no course in industrial chemistry will of itself make an industrial chemist of any student who has not absorbed "pure" chemistry from other courses, as well as a proper share of mechanics, mathematics, and physics. The function of the instruction in "applied" chemistry as distinguished from "pure" chemistry must be to broaden his horizon by permitting him to see beyond the test tubes, beakers, and porcelain dishes, so necessary in the analytical or organic laboratories, to the tubs, vats, filter-presses, or acid chambers of the works; and to realize, even though it be imperfectly, the new factors, such as use of power and cost of materials and labor, which enter into the technical problems, but are not taken account of in the ordinary problems of the student analyst.

The course naturally divides itself into the lecture or recitation-room instruction, and that in the laboratory. These parts should be coördinated, and the former should deal with typical operations common to many processes, such as filtration, lixiviation, evaporation, etc., followed by the descriptions of the process of manufacture of important products. Details should be given with moderation and after thoughtful selection, and the descriptive side should be accompanied by, or perhaps subordinated to, a careful exposition of underlying reasons, and whenever it is possible, full emphasis should be laid upon the useful applications of the principles of chemistry, mechanics, or physics. It is evident that such a presentation of the subject can only be adequately made by one who has had some vital contact with chemical industry through actual service or frequent visits, and the man who combines with such an experience the natural aptitudes of a teacher is already widely sought and is likely to be still more generally desired by educational institutions throughout the country.

The aim of such instruction obviously cannot be to impart a knowledge of the manufacture of any one product extending to minute details, which would probably be of little or no value to any single member of a group of students. It may, however, be of great service in affording a classification of processes and a general conception of the methods employed to handle materials of various sorts, or to secure certain ends.

The value of the classroom instruction is greatly enhanced by trips to industrial establishments taken under the guidance of the instructors (short trips during the school year, with longer journeys for such as are able to participate in the summer). Here, too, the breadth of expe-

rience of the instructor is an important factor, for the benefit derived increases in geometrical ratio with the effectiveness of the preliminary talks designed to render the observations of the student acute and intelligent. In this connection one can hardly express too much appreciation of the courtesies extended by the manufacturing interests in making such visits possible, as they must often become sources of greater or less inconvenience. Of their real benefit to those who participate in them, no one who has had opportunity to observe results will probably raise a doubt. They are particularly helpful in bringing to the attention of the student the need and usefulness of breadth of knowledge both within and without his professional work.

But a question was long ago raised whether it is necessary to depend entirely on these visits to established plants to emphasize the precepts of the classroom instruction in industrial chemistry; that is, to what extent laboratory instruction in industrial chemistry is possible or advantageous in educational institutions. The conclusions reached are varied. Some will express the conviction that nothing of the sort should be attempted; others will approve of courses which are essentially those of inorganic preparations on a somewhat large scale; still others will maintain courses which aim to illustrate, through the preparation of a few products on a moderate scale, the nature of the factors entering into the problems of the industrial chemist and the kind of difficulties which he has to meet and overcome; and there is the further possibility of the establishment of a plant upon a semi-industrial scale, which should be run continuously and in which the student should serve a brief apprenticeship, devoting himself, for this space of time, entirely to this work.

Experience seems clearly to justify the establishment of laboratory courses in this subject, but they should not be those in which the preparation of certain materials is the principal end sought. To be advantageous they should be so conducted as to bring to the student a realization of the meaning of what has been called the "economics of chemistry." Such a course has been fully described by Dr. W. H. Walker in *The Technology Review*, Volume VI, page 163. The experiments "are selected not so much for their intrinsic merit or relative importance as for the ease with which they are adapted to laboratory conditions and the exactness with which the several factors making up their final efficiency may be controlled." Some of these factors are: cost of materials, cost of reagents, mechanical difficulties

to be overcome and types of apparatus and kinds of material available, the control of reactions involved, the use of scientific tables in technical work, the use of instruments of technical accuracy little known in other lines of work, the value of waste or wash liquors and their utilization, the purity of the product, and the presentation of a systematic report. Such factors as the cost of labor or power, the depreciation of plant, or interest on investment are not, of course, directly subject to determination in the laboratory; but these are taken up and discussed in conference. The work is further arranged in such a way that several students will work simultaneously upon a given problem, a single factor being altered by each, the final results being discussed in conference, and in all this the spirit of investigation is carefully fostered.

In a course of this character no claim is made that actual industrial conditions are duplicated; it is the industrial trend of the course which constitutes its value, and the things which it suggests and the points which it raises for discussion and conference are its vital features. Such suggestions are avowedly based upon work which is upon a very small scale in comparison with an industrial plant, and many of the problems of the latter can only be dimly realized by the student. The other suggestion, that a plant, composed of units from a limited number of large chemical plants for the production of such products as muriatic or nitric acids or electrolytic bleach liquor, should be established and operated by students, contemplates a closer approach to working conditions, and would possess unquestionable advantages. Against these must, however, be placed the very considerable cost of housing, establishment, and maintenance of a plant of this sort, the present (although not insuperable) difficulties in adapting the work in such a plant to the schedules of the college year, and the fact that this would, after all, be but another stage in the progress toward actual industrial conditions without having attained them. Just where the balance between these considerations would lie is a question which deserves the serious thought of those entrusted with the charge of chemical instruction.

The term "industrial chemist" has become closely synonymous with that of "chemical engineer" in recent times, and the chemical engineer is defined as one versed in chemical science, who also possesses such a knowledge of mechanics and engineering that he is capable of transforming the chemical reaction of the test tube or beaker into a plant capable of turning out some product of the reaction on a technical scale

and at a profit. It is undeniably true that this is the general type of man sought for today, and in his education time must be found for a fundamental training in mathematics, mechanism, mechanics, and steam engineering, as well as in the principles and practice of chemistry — a task to which five years rather than four need to be devoted. This breadth of education is absolutely demanded in positions of superintendence and wide responsibility, and it is highly desirable even in the less prominent positions, but its acquisition necessarily lessens the time which can be devoted to the strictly chemical development of the student, and it is to be hoped that in the not too distant future there will also be an increasing call for men to take positions in technical establishments the preparation for which will involve an even more thorough chemical training. Research laboratories are apparently growing in favor in the industrial field, and the establishment of endowed laboratories for technical chemical research in connection with technical schools may be one of the welcome developments of the coming years.

The education of the technical chemist or chemical engineer must, then, be far from being dominated by the technical or commercial point of view. A knowledge of "pure" science, whether chemical, physical, or mechanical, must always be his mainstay rather than his experience with applied science. Added to this, he must have the ability to think clearly and independently, not merely to follow, but to lead. With this at his command and with ability to get on with his fellowmen, his success is reasonably assured.

THE RELATION BETWEEN TECHNICAL EDUCATION AND INDUSTRIAL PROGRESS[1]

By ROBERT H. RICHARDS

All clear thinkers agree that there *is* a close relation between technical education and industrial progress, but that to be effective the education must be of the right kind.

Industrial progress in the last fifty years has consisted in seeing an opportunity and in finding a way to make the most of it.

About 1870 in the United States, the opening up of new territory called for iron for railroads and for agricultural tools. The best iron blast furnaces of the United States were then making something like 25 tons of pig iron a day. They were in the hands of ironmasters who learned their trade at the furnaces and did their work as they had been taught by their predecessors. Any suggestion of change from the adopted method drew out the reply, "That was tried in my grandfather's time and proved to be a failure." The furnace method had been at a standstill for years, and improvements were apparently impossible. At about this time the American scientific schools began turning out their graduates, and the Americans who had obtained similar training abroad returned. These men brought in a new leaven, and the resulting increase in the work of a furnace is represented by the following figures:

Charcoal Iron Furnace

Date.	Hearth.	Height.	Capacity.
1870	2 feet 6 inches	39 feet	10 tons each 24 hours
1890	6 feet 7 inches	60 feet	130 tons each 24 hours
1904	8 feet 6 inches	70 feet	160 tons each 24 hours

[1] Read before the Mining Society of Nova Scotia at Halifax, March 22, 1906.

ANTHRACITE IRON FURNACE

Date.	Hearth.	Height.	Capacity.
1870	10 feet 10 inches	40 feet	25 tons each 24 hours
1890	11 feet 4 inches	73 feet 11 inches	100 tons each 24 hours
1904	14 feet	100 feet	465 tons each 24 hours

COKE IRON FURNACE

Date.	Hearth.	Height.	Capacity.
1897	10 feet 6 inches	75 feet	207 tons each 24 hours
1904	12 feet 6 inches	85 feet	321 tons low grade ores
1904	15 feet 4 inches	100 feet	600 tons high grade ores

LEAD BLAST FURNACE

Date.	Hearth.	Height.	Capacity.
1870	2 feet square	12 feet	12 tons
1880	36 x 100 inches	14 feet	60 tons
1890	42 x 140 inches	. .	120 tons
1900	48 x 164 inches	. .	160 tons

COPPER REVERBERATORY FURNACE

Date.	Hearth and height.	Capacity.
1878	15 feet 0 inches x 9 feet 8 inches	12 tons
1887	21 feet 2 inches x 12 feet 8 inches	24 tons
1894	35 feet x 16 feet	50 tons
1904	50 feet x 32 feet	90 tons
1906	112 feet x 19 feet	350 tons

Copper Blast Furnace

Date.	Hearth.	Height.	Capacity.
1881	28 x 28 inches	8 feet	35 tons
1883	48 inches diameter	10 feet	60 tons
1885	48 x 121 inches	8 feet	100 tons
1900	56 x 180 inches	18 feet	400 tons
1904	56 x 180 inches	18 feet	500 tons
1906	56 x 612 inches	18 feet	1,600 tons

The same wonderful progress is true of the Bessemer process. When it was first introduced into the United States, about 1868, two converters could work five charges of five tons each, 25 tons in all, each day. Now, through the improvements brought in by the introduction of scientific methods, two converters can make 900 to 1000 tons of steel a day. Names prominent in this advance are Holley, Wood, Schwab, and others.

The story of the copper furnaces has been the same. The reverberatory of 1878 had a hearth 9 x 15 feet and worked 12 tons in twenty-four hours. The Argo, Colorado, reverberatory now has a hearth 19 x 112 feet and works 350 tons.

The lead furnaces of 1870 were 24 inches square in section and smelted 12 tons in twenty-four hours. Now they have cross sections 48 x 164 inches and smelt 160 tons a day.

Such extraordinary development as this came, not without resistance from conservatism, as the direct effect of the application of science and the scientifically trained mind to the subject in question. It is true, self-made men have been present in this wonderful procession, have done their share in bringing on the advance, and have done it nobly, but they walked side by side with the technically educated men and had their trained chemists. They read and studied the current literature.

Having noted a few main facts of the development along certain lines, let us look for a moment at some of the obstacles which had to be overcome.

First we come to the classical college as it then was. The speaker's own experience may be cited: He had been at a classical preparatory

school until two years older than the normal age. He worked industriously and seriously, but made little progress. The work was always uphill, and required great effort to keep his attention. At the last moment a change was made. Instead of going to a classical college he went to a scientific school, where he was immediately fascinated by the study of scientific phenomena of physics, chemistry, geology, engineering. Instead of having to drag himself to his books he could not keep away from them; instead of reading books of ancient history and mythology to please his teacher he now tried experiments to demonstrate laws of nature for himself, and read the authors at first to see if his demonstrations accorded with theirs, but afterward to see if they agreed with him.

The right to question even what is written in books is not only the right but the duty of every scientific man.

The speaker's experience has been that men brought up on the classics have their best field in literature, law, theology, and politics, where oratory and logic of persuasion count most, and that those who go from this training into mining, metallurgy, and manufacturing have a certain bondage to authority to overcome. But when men of this class are emancipated from the bondage to authority they furnish the finest examples of intellectual ability.

The men who have been graduated from a scientific school have been taught to observe, to record, to collate, to conclude — to observe the phenomena as they are occurring, to record what they see as it really is, without a bias, to collate the results, correcting instrumental and personal errors and tabulating results, so as to *conclude* wisely what is to be expected from the premises. Men who have been taught by this method have learned how difficult it is to see and how important it is to keep an open mind in order that wisdom may have a chance to act. The modern scientific man is most courageous in experimenting; his imagination has been highly cultivated; nothing daunts him; he annihilates time and space, and does in a year the work of a former generation. He knows that, while he may be disappointed again and again, if he can only find the true cause and sequence of facts he can then press the button and the results will follow.

"Why not let opportunity make the man?" is asked. Dr. Drown has answered: "A technical school is a device to save time. Man's days are still three-score years and ten, but now he crowds as much into them as Methuselah did into his 969 years."

Mr. Chamberlain, of England, says: "I do not think it is necessary for me to say anything as to the urgency and necessity of scientific training. . . . It is not too much to say that the existence of this country (England) as the great commercial nation depends upon it."

While the classically educated men have been the mainstay of society for a long time on the lines where they are strong, they did not bring about the modern industrial progress or help in it until the modern engineering schools led the way. Since that time the colleges have come into line, each with its engineering and chemical departments.

The Eye and the Mind

The importance of hand work in the school for demonstrating the fact that when we look at a thing we do not see it all has been proved beyond all doubt. In the speaker's own experience he constantly hears from some student, "I have tried that machine for concentrating this ore, and it is a failure." The teacher's reply is, "Are you sure that you tried the experiment rightly and saw everything that was going on?" A repetition of the test frequently brings a reversal of the decision. The speaker has known many cases where improvements have been turned down simply because the eye and the mind of the experimenter have not been sufficiently trained to grasp the bearings of what was being done.

The effect of the practical school training upon an engineer is well shown in the following instance: The engineer referred to sent a drawing of an intricate forging to a firm in one of the Southern states. The manager sent it back, saying, "The piece cannot be made." The engineer, thinking that the other had misunderstood the drawing, made a wooden model of the exact shape he wished the finished piece to have. This he carried over to the works in person. The manager said, "Not only are we unable to make this piece, but the man does not live who can make it." The engineer asked, "May I have the use of a forge?" This was granted, and all the expert blacksmiths of the place gathered around him to see this greenhorn of an amateur make a fool of himself. He worked through his task logically step by step, and brought out the finished piece just like the wooden model. He was then asked by the manager, "Did you ever see one made?" "No." "Did you ever see one like it?" "No." "How did you know one could be made, and where were you taught to make

it?' "I was taught the principles on which everything is made at the Massachusetts Institute of Technology in Boston." At this reply the manager said, "I don't believe a word of it."

The above is a very good illustration of the different ways in which the two classes of minds look at things. The trained scientific mind is ready to undertake anything. The rule of thumb man will go as far as he sees, but his imagination fails him. The former can mentally analyze and reconstruct, while the latter can do only what he has been taught.

The use of the shop for the development of skill and imagination is well illustrated in this way: The teacher of forging shows the pupil in successive lessons how to draw a piece of iron, how to make a piece round or square, how to punch an eye, how to make a weld, how to make an offset and a rivet. He then asks his pupil to make a pair of blacksmith's tongs. The answer comes: "But I can't. I never did such a thing in my life." The teacher is inexorable, and the pupil begins. He finds to his surprise that the task before him is simply a grouping together of a series of steps, each of which he has already mastered. The first tongs a good student makes will compare well with the work of an average country blacksmith who has had years of experience.

The change from the rule of thumb man to the scientifically trained man has not been without its difficulties, most of which had their origin in the jealousy of the former and the inexperience of the latter.

It is interesting to note the devices to which the young scientist has to resort in order to overcome the barrier of conservatism. For example, an engineer, seeing great waste of good material taking place at an iron blast furnace, at first asked permission of the ironmaster to save it by putting it in the furnace. He was met by the stock remark, "My grandfather tried that and proved it a failure." The young man then tried the opposite tack. Analyses of the usual ore and also of the said waste material were placed side by side on the manager's desk. This was done repeatedly and as an apparent coincidence, until the manager noticed one day that the alleged waste material was richer than the ore, and he said, "I believe that stuff would make iron, after all," and ordered that the trial be made. As soon as it became the act of the manager and he received the credit for it the saving was all right and the thing to be done. When the young

scientist found that his diplomacy had triumphed in the first case he tried it again on another line. In this way, time and again, advances were made, until the real source of improvement was recognized by the capitalists, and the old, conservative manager gave place to the young, progressive one. But this was only after the young scientist had gained sufficient experience to make it safe.

An exceedingly interesting case of the breaking down of conservatism shielded behind barriers of religion and nationality, as well as international distrust, occurred to a young American who taught a school in India. He recognized early that the teaching of tool work must be more forceful for his purpose than book work, but he saw also that to introduce foreign tools would excite antagonism at once. He therefore set the Hindu young men at work designing a tool to cut wood. A little careful, unnoticed guiding on the part of the teacher brought the young designer to the modern approved form, but the tool was the Hindu's own design. He had not only made it, but he had created the idea. The credit was his. The barrier thus broken soon fell, and progress was rapid.

Many instances might be given of the lagging of industrial progress because advantage of technical knowledge was not taken. For example, in geological work the speaker once knew a young school man who, at a mining summer school, was taken by a local home-taught mineralogist and geologist at the eastern slope of the Rocky Mountains in Colorado to visit certain outcrops around the vertical coal seam being worked there. The young graduate quickly reconstructed from the fragments the probable geological structure of the place, including a syncline with axis north and south and the coal mine on the western slope, combined with a horizontal bedding extending indefinitely eastward. From these scattered fragments he predicted that the coal seam would be found 200 feet deep, more or less, in the eastern plain, in undisturbed and therefore better condition than in the coal mine then being worked. He reported his conclusion to the manager and to other prominent men. They all turned it down as the dream of a schoolboy or the notion of a "scientific cuss."

Twenty-five years later it was found that many square miles of coal did underlie those plains. In this instance not only the business man and coal manager could not see it, but the home-taught geologist had not thought of it until his attention was called to it.

In another instance a young man went to Maryland to survey coal

property in a syncline valley. He noticed that where the central river bottom and the branches cut below the coal the following of outcrop was easy and the survey simple, but the outside croppings were blind. To run these in his survey he designed a geometrical rule by which he ran long distances of outcrop, coming out at the next visible sign near enough to plot the lines. The young country surveyor who helped him was greatly taken with this plan, and laid it up in his mind.

Years afterward the latter met the former and said: "Some New York men came down here and wanted to buy coal land outside our lines. I told them that there was no coal there and that they would be disappointed. They persisted, made their purchase, put down borings, but found no coal." Here the business man refused the advice of the scientist, and suffered in consequence.

Pure logic often forms a bulwark behind which conservatism can rest; that is, pure logic builds upon facts a structure of argument that, if certain things are known, certain other things will follow. But if the supposed facts turn out to be incorrect, then the whole structure falls. The difference between the logician and the scientist is that the logician assumes his premise to be correct and the scientist doubts everything. The comment comes from Edison, Whitney, and others in words to this effect: "In questions of industrial progress no man living knows *all* the facts, and so the questions of success or failure cannot be answered by logic until not only every probable and possible thing has been tried, but every impossible thing also."

As previously pointed out, technical education is acquired not only in the school, but in contact with fellow-workers.

In the United States the interchange of visits and cordial comparing of notes have always been the rule. Some change in the way of shutting out visitors is now coming in, which is to be regretted. An instructive example along this line came in a Pittsburg meeting of the American Institute of Mining Engineers. On one of the excursions two old friends were conversing, and one said: "I always thought my works were the most advanced of any. In consequence I have never asked others to visit me and have not visited them. I now find that I am at the tail end of the procession."

Not only are men blind and conservative, but nations are still slower to adopt new ideas.

Sir Norman Lockyer says: "Britain in the middle of the last

century was certainly the country which gained most by the advent of science, for she was then in full possession of those material gifts of nature — coal and iron — the combined winning and utilization of which, in the production of machinery and in other ways, soon made her the richest country in the world, 'the seat and throne of invention and manufacture,' as Mr. Carnegie has called her."

The beginning of the decline of English supremacy in manufactures has been said to date from the time when A. W. Hofman left England to go to Germany because a few thousand pounds needed to pay him and equip his laboratories were not forthcoming. The government officers who should have appreciated the situation and his value to the kingdom did not, and as a result his wonderful inspiration and storehouse of experience was taken from England and given to Germany.

In his presidential address before the British Association in 1903 Lockyer also said: —

"Our position as a nation, our success as merchants, are in peril chiefly — dealing with preventable causes — because of our lack of completely efficient universities and our neglect of research.

"We now know, from what has occurred in other states, that if our ministers had been more wise and our universities more numerous and efficient, our *mental resources* would have been developed by improvements in educational method, by the introduction of science into schools, and, more important than all the rest, by the teaching of science by experiment, observation, and research, and not from books. It is because this was not done that we have fallen behind other nations in properly applying science to industry, so that our applications in that direction are relatively less important than they were. But this is by no means all. We have lacked the strengthening of the national life produced by fostering the scientific spirit among all classes and along all lines of the nation's activity; many of the responsible authorities know little and care less about science; we have not learned that it is the duty of a state to organize its forces as carefully for peace as for war; that universities and other teaching centres are as important as battleships or big battalions; are, in fact, essential parts of a modern state's machinery, and as such to be equally aided and as efficiently organized to secure its future well-being.

"Suppose we were to set about putting our educational house in order, so as to secure a higher quality and greater quantity of brain

power; it would not be the first time in history that this has been done. Both Prussia, after Jena, and France, after Sedan, acted on the view:

> When land is gone and money spent,
> Then learning is most excellent.

"After Jena, which left Prussia a 'bleeding and lacerated mass,' the king and his wise counselors, among them men who had gained knowledge from Kant, determined, as they put it, 'to supply the loss of territory by intellectual effort.'

"After Sedan, a battle, as Moltke tells us, 'won by the schoolmaster,' France made even more strenuous efforts. The old University of France, with its 'academies' in various places, was replaced by fifteen independent universities, in all of which are faculties of letters, science, law, and medicine.

"But even more wonderful than these is the 'intellectual effort' made by Japan, not after a war, but to prepare for one.

"The question is, Shall we wait for a disaster and then imitate Prussia and France, or shall we follow Japan and thoroughly prepare by 'intellectual effort' for the industrial struggle which lies before us?"

The Effect of Technical Education in the United States

In the United States the most interesting aspect of industrial progress is the atmosphere of alertness that prevails, in contrast to the conservatism of the old country. It is so contagious that it affects all who come. This is well illustrated in the case of a Welsh copper metallurgist who came at an early date to the Rocky Mountains, and soon absorbed progressive ideas. Just after he had rebuilt his copper furnace so that its capacity should be increased from 40 tons to 80 tons he received a letter from a friend in the old country, saying: "We are contemplating increasing the capacity of our furnace from five tons to six tons. Do you think it would be safe to make the change?" The former replied, "After careful consideration of your question for a week I think that it would be safe."

How comes it that there is this alertness and adaptability? It is partly in the air. The speaker believes that the modern schools of the class of the Massachusetts Institute of Technology have had a large share in this. They take the boy from the high school and, before he has lost his youthful enthusiasm and his quickness in learn-

ing, equip him with principles, blaze out his path for him, and turn him out well started along the road to become an engineer. The fact that he begins his practical work in the world before he has passed the age of greatest acquisitiveness is a very strong point in favor of a course involving only four years from the high school.

Sir Norman Lockyer asserts that "in the United States the most successful students in the higher teaching centres are snapped up the moment they have finished their course of training, and put in charge of large concerns."

(The speaker differs with the last part of this quotation. He certainly hopes that none of his pupils will be rushed ahead at quite that speed.)

In Britain, on the other hand, apprentices who can pay high premiums are too often preferred to those who are well educated, and the old rule of thumb processes are preferred to new developments.

It has repeatedly been noted that in England the training of skilled workmen and foremen is carried to a high degree of excellence and the training of engineers and leaders has been neglected; but that the exact opposite is the case in the United States.

At this stage of industrial development everybody believes in education of the right kind as a help, and the natural question is, "What is the right kind?" The speaker thinks that kind represented by the Massachusetts Institute of Technology.

The United States technological schools, engineering departments of universities, and the state mining schools all give courses in the various lines of engineering and chemistry. Capital for this training has been furnished liberally by individuals, and high tuition has been paid by students who see the immediate profit coming from the investment. The great progress in the United States dates from their beginnings.

In Germany the Technische Hochschule of Charlottenburg fits men for the various engineering professions and for chemistry. A recent catalogue showed 3,000 students, the length of the course about four years, the number of graduates eighty.

The students of the Technische Hochschule are allowed, to a limited extent, to participate in the tests of the testing station at Lichterfelde in the capacity of assistants. But as Lichterfelde is one of the suburbs of Berlin and Charlottenburg another they are not suited for close association with each other.

The other German states also have Technische Hochschulen.

In regard to the English schools, according to quotations from Lockyer, the technological schools have not reached the standard of those of Germany or the United States. The speaker has not been able to corroborate or refute this statement on account of the brief time allowed to prepare this address.

Modern education is no longer a log with Mark Hopkins at one end and a boy at the other. It is no longer Greek roots and Latin tenses. The education we have referred to deals with the principles of chemistry, physics, electricity, mechanics, metallurgy, and ore dressing as underlying industrial progress.

To elucidate the principles laboratories are needed, supplied with the requisite apparatus.

The laboratories of ore dressing with which the speaker is connected are supplied with small machines with which to test the concentration of ores. The small size diminishes the first cost, the running cost, and the exhaustion of students from handling heavy weights, and yet the apparatus is large enough to decide all the important questions of designing a mill process. They can tell when crushing to 16 m.m. 8, 4, 2, or 1 m.m. in size, whether the slimes saved by the coarse crushing more than offset the better and cleaner concentration with fine crushing, and many other important points.

The question is often asked, "Should professors do expert work?" The speaker thinks, "By all means, yes." Their teaching is greatly strengthened by having a little connection with the world of action. It helps to keep them awake and up to times in the problems of the day. They should not, however, allow it to rob the students of time to which they have a right. Moreover, the outside practitioners would be very nervous if the school men, with the added prestige coming from their position in the school, should appear in serious competition and take away much of the business.

Should research laboratories be established? The arguments are strongly in favor of them. In the United States research laboratories are being installed in connection with schools and are helped by the Carnegie Institution.

The large corporations are realizing the importance of research laboratories. The General Electric Company and the Westinghouse Company both have laboratories covering acres of floor space. The former has from twenty to thirty assistants constantly on new work,

so great is the field for industrial improvement and consequent profit to the company.

At Berlin, Germany, the Government Testing Works (Versuchsanstalt) at Lichterfelde-West, have the following departments:

Testing metals for tension, compression, torsion, elasticity, conductivity, heat-treatment, corrosion, etc.

Testing building materials, such as brick, mortar, cement, concrete, for strength and durability, density and absorption.

Testing paper for strength, absorption, and filtering power, together with examination by the microscope and other means.

Testing metals by metallography — that is, etching, polishing, microphotography — determining the eutectic curves of metals, and other tests.

Testing substances by chemical analysis. There is a complete chemical laboratory for chemical analysis of metals, of materials used in manufacturing, and of gases.

Testing oils for fluidity, flash point, ignition point, refractivity, and for sulphur by vacuum distillation, fractional distillation, or other means.

When samples are tested without charge the results are published in the annual report for the benefit of the public. Those that are paid for, on the other hand, are treated as confidential.

There are also in Berlin an establishment for standard weights and measures, which is of great benefit to manufacturers and users for purposes of comparison, and the Berlin Physikalische Reichs-Anstalt, an institution for research in chemistry and physics.

The other German states have testing stations of the same general character as that of Berlin, Prussia, but they are not developed to quite the same extent.

In the United States the Watertown Arsenal has a department for testing, in charge of the Ordnance Department of the United States Army. There are three varieties of work done at this station:

1. Testing for the Ordnance Department of metals and materials for guns, etc.

2. If the above work is not pressing general tests of engineering materials are undertaken. The results of these are published.

3. Work for individuals for a fee. The results of these tests are considered confidential.

The United States Geological Survey is doing work on the testing of structural materials and fuels. During the summer of 1905 it

undertook also the testing of black sand, in which the speaker took part. From the sea and river sand, as well as the sand from hydraulicking and dredging for gold, minerals of commercial value were obtained, namely, magnetite, chromite, garnet, monazite, and zircon. In some cases they will prove to be of economic importance.

The Bureau of Forestry of the Department of Agriculture is making timber tests.

Many schools and colleges do some testing of materials of engineering and of ores and of chemical products for individuals independently of the government.

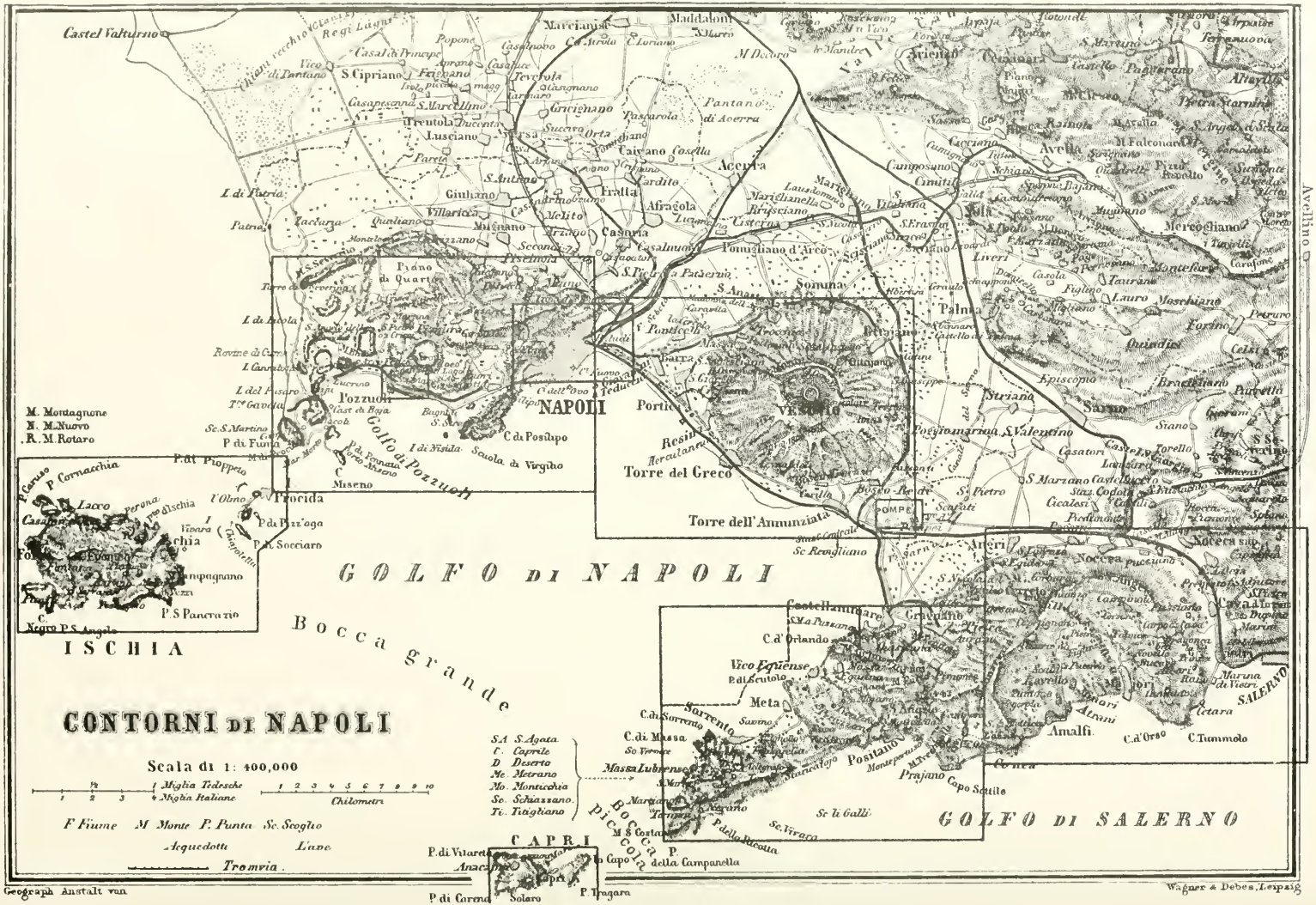
An instance of the effect of inspection and testing is here given:

When an army officer, inspecting the pistols of a large manufacturing concern in the United States during the war of 1862, rejected a large order because of variations in calibre and other slight deviations, he appeared to be doing a harsh act and one hard for the manufacturers to forgive. He really made the fortune of the manufacturers, because they at once doubled up on the care expended in the construction of the pistols, produced a first-class article for sale, and greatly increased their business. This is also a good instance of the benefit of government testing works to a country.

In conclusion, how shall the advantages of participation in the general industrial prosperity be gained?

The reply seems to come on all sides — establish research laboratories, testing laboratories, and technological schools or engineering departments in universities.

If a country somewhat behind in the race seeks to catch up and finds gifts from private fortunes are not available, it is surely good politics, as well as good patriotism, to use some of the taxpayer's money to start and carry on these good works on a liberal basis.



MAP OF MOUNT VESUVIUS AND VICINITY

THE VOLCANO VESUVIUS IN 1906

By T. A. JAGGAR, Jr.

In the spring of 1905 the summit of Vesuvius was unusually sharp-pointed, the crater was small, and a considerable growth in the height of the conelet on the summit took place during the year. In March of 1906 the height of the volcano above sea level was at least 4,350 feet. The active cone rises from a platform some 1,800 feet high, which is in reality the rim of an ancient stage of the cone when perhaps the volcano was much larger. This rim appears as a bench on the south and west and rises into a rugged encircling mountain scarp on the north and east, known as Monte Somma. Between Monte Somma and Vesuvius is the Atrio del Cavallo, a desolate valley 1,500 feet deep, with rugged cliffs on the side of Somma and long cone slopes on the side of the active volcano (see map). From the crater to Monte Somma the distance is a mile as the crow flies; from the crater to the Bay of Naples five miles in a southeast direction. Here the coast trends northwest. The places affected by the recent eruption and their distances from the crater are as follows: Boscotrecase, due south three miles; Torre Annunziata, south four miles; Ottajano, northeast, back of the ridge of Monte Somma, three and one-fourth miles; San Giuseppe, east-northeast, four and one-half miles, also shielded by the Somma ridge; Royal Observatory, one and two-thirds miles west-northwest; Naples, eight miles west-northwest. The Observatory is on a pronounced eminence of old lava, and both north and south of it are *coulées* of lava of recent origin. Past the door of the Observatory, much to the disadvantage of its magnetic instruments, run the cogwheel electric trams of the Cook Vesuvian railway. These made connection, prior to the eruption, with a very steep inclined plane funicular railway at the foot of the cone above the Observatory. There was a small station at the top and bottom of this last lifting device, which was designed to transport tourists to the immediate proximity of the high crater.

From the Italian point of view an eruption of Vesuvius means great outflows of lava — molten liquid rock. This outflow may be more or less accompanied by the *pino*, or pine-tree steam column laden with dust. The name is derived from a supposed resemblance in the form of the cloud to the Italian pine, with its straight stem below and spreading oval or funnel-shaped mass of foliage above. The present eruption was by no means unheralded. In 1904 there was flowing lava in the Atrio, checked coincidently with an explosion in the crater in September of that year. A year ago, in May, 1905, the cone split near the summit on the northwest side and very fluid lava flowed out. This flow, plainly visible from Naples, continued with varying activity until April 4, 1906, the time of the beginning of the present eruption. This eleven months of lava, lasting over a dry season (June, July, and August) and through another season of rain, might well give the scientific observers cause for apprehension. The contact of large masses of underground water with such incandescent slags could hardly fail to produce an explosion eventually. In the afternoon of April 4, 1906, a magnificent dense black "pine tree" was seen from Naples against a clear blue sky. The column rose obliquely 3,300 feet and then bent to the southeast. The small conelet caved in. The lava flows on the northwest had ceased to move, but a new mouth opened about 500 feet below the summit on the southeast side of the cone and gave vent to a flow which trickled southward. Heavy black sand fell at Naples.

On April 5 another lava mouth burst open 1,300 feet lower, and the next day a third 600 feet lower still and in the same radial line from the summit with the first two. Apparently the three mouths, in such a case, mark the extension of a rift or split from the crater outward and downward, like the crack from the top downward of an opening chestnut burr. The pressure of the rising lava finds it easier to rift the cone and so escape than to well up to the crater's edge. The common notion that the lava overflows the crater and rushes down in floods is erroneous. The lowest mouth was more than halfway down the mountain, and from this orifice nearly all the damage by lava was done. The stream divided in two, and part ran east and part south. The latter soon invaded cultivated land and destroyed some houses. The molten rock moved slowly but inexorably, like a mighty snake, seeking the lowest ground, following gullies when gullies could be found, but creeping onward always, crusting over the surface, cracking and making a tumble of porous bowlders at its front and on its

surface. Its most rapid movement was estimated at 16 feet per minute, excepting, perhaps, at the time of first outburst, when it was still quicker. On April 7 the lava was within a quarter mile of Boscotrecase, and it had flowed nearly two miles. Boscotrecase was a closely built masonry town, with a large church and numerous villas, and much of the town was on flat land at the confluence of two small valleys rather than on the intervening spur.

About eight P.M. of April 7 terrific explosions took place in the crater, and the "cauliflower" cloud rose three or four miles into the heavens. Large, red-hot blocks of rock were hurled out in a direction inclined upward to the northeast, towards Ottajano. These bounded down the flanks of the cone. Detonations increasing in violence and frequency were heard at Naples. The cloud was shot through with splendid electrical discharges from node to node of the dry, dust-charged steam whirls. The lightning was described by an observer at the Observatory as being nearly incessant and snapping, with a "rik-a-tak," spark-like quality, though frequently it was forked as in a thunder storm. At ten o'clock a fourth lava mouth opened, and new activity was given to the other flows, overwhelming Boscotrecase in two lurid streams and only stopping at the outskirts of Torre Annunziata. At eleven P.M. sand and *lapilli* fell in showers in Naples and in torrents on Monte Somma, Ottajano, and San Giuseppe. The overpowering weight of this snowstorm of gravel was too much for the flat and tiled roofs of the Italian stucco houses, and Ottajano simply *fell in*, the crumbling walls adding to the volcanic *débris*. There were no strong quakes, gases, thunderbolts, or heated blasts and no fires due to volcanic cinders. The material which fell at Ottajano retained no considerable heat. At Boscotrecase, however, crushed by creeping lava, fire necessarily aided in the work of destruction. At Ottajano many persons were buried in the fallen houses and still more in the church at San Giuseppe, where over two hundred were united in prayer at the fateful moment when the roof collapsed. There were almost no lives lost at Boscotrecase. The experience of Dr. Matteucci, Mr. Perret, and the carbineers at the Observatory was remarkable. Throughout the evening of April 7 the activity of the cone was recorded at the Observatory by incessant rocking, increasing showers of stones, some of which finally reached five pounds in weight, and a noise like a thousand boilers letting off steam — a sound of rushing winds. The vibrations were continuous for twenty-four hours. The

party dared not remain indoors, and they finally made a camp in the open. The conditions that night finally became intolerable, and the brigadier in charge gave the order to move down the mountain. They retreated to a house halfway down, and returned to the Observatory next day. The buildings were found intact, but dust had sifted into everything, necessarily injuring the instruments. At Naples, on the night of April 7–8, some slight earthquake shocks were felt and heavy detonations were heard. Mr. Perret, in describing to the writer the events at the Observatory, mentioned no heavy detonations. In this respect the experience of these observers suggests what was invariably the case at Mt. Pelée and Soufrière — that the sounds heard at a distance were greater than on the volcano itself. This implies some phenomenon of sound-shadow not as yet understood.

On April 8 the volcano was still pumping into the air its colossal dust cloud, charged with lightnings. The ash became finer and reddish in color. Sometimes, when the dust fell simultaneously with raindrops, it became agglutinated into tiny balls of the size of fine shot, which made distinct layers of such globules. On April 9 the crest of the cone was seen to be truncated and much lower than before the eruption. After this date the eruption steadily diminished in violence, until by the 23d, when the writer first saw the mountain, only quiet billows of white steam were rolling off, usually masking the crown of the cone with a heavy cap of cloud. During this period, however, there was one interruption to the tranquillity of those who remained at the Observatory. On the 18th of April, from noon until midnight a strong wind blew from the east-southeast and forced the deadly gases of the crater down to the Observatory hill. The air became irrespirable, and several persons were nearly overcome. It was surmised from the symptoms that carbonic acid gas and sulphuretted hydrogen were the principal gases present. At midnight the wind changed and the air became pure again.

Vesuvius on the morning of April 25, covered with its mantle of whitish dust, appeared like the pictures of snow-clad Fusiyama. The dust gave a weird, ghostly appearance to the landscape, mantling over and obscuring the contorted folds of ancient lava. The powdery appearance was confined to the volcano and its flanks and diminished with increasing distance from the crater. At about eight A.M. the writer, with three companions and a guide, started from the Observatory to make the ascent. The wind was blowing from the west. Great steam billows boiled up silently from the crater, and at intervals of a minute

or two either broke away in a cumulus cloud or settled down on the mountain, temporarily obscuring the crest. Throughout the day the wind increased, and as there had been little rain the sand and dust were borne in whirls over the mountainside, frequently obscuring everything, making breathing difficult, and penetrating eyes, ears, clothing, cameras, and field glasses most unpleasantly. The route followed first the lower railroad bed, and then the western profile of the cone straight up, along about the course of the demolished funicular. The railroad below the foot of the cone is occasionally recognizable; above it is almost obliterated. The stations are absolutely gone. Here there is a bent rail sticking straight up into the air; there is a stretch of track still tied together by the sleepers, but bent down the mountain at a right angle, as though the whole roadbed for a short distance had been swept downward by an avalanche. Everywhere a pall of sand and gravel from 1 to 6 feet deep, scoured and etched by the wind to show cross bedding, ripple-drift patterns, and arrow-shaped accumulations in the lee of pebbles or other stationary objects. Here and there on the higher slopes there are large, angular, new-fallen rock fragments up to five feet in diameter. Much of the upper cone slope is practically hard rock, the descent being so steep that the new material slid down and accumulated in drifts at the bottom. The slope of the cone makes an angle of about 30° with the horizontal.

Climbing the higher slope was not especially difficult, as the footing on the spurs was hard, though the gullies were filled with deep, soft sand. By following a zigzag route the steepest places were avoided. The hard spurs are either actual bed rock of old lava or closely plastered and cemented rock fragments so packed that they could slip no farther. The slope is so steep, especially in its middle portions, that great care is necessary to prevent starting bowlders down on climbers below. The steepness increases to a point near the crater's edge, when the slope becomes a little flatter. A volcanic cinder cone is peculiar in that the inflections of its profile are such that the actual edge of the crater is in view at all times; what appears to be the summit *is* the summit, as may be seen by the steam billows just beyond, and when the edge is reached the abrupt precipitous fall-off is very sudden. Near the border of the crater the gentler slope permitted accumulation of deep gravel beds, making the last steps of the ascent very arduous. This was enhanced by increased violence of the wind, and the bombardment of tingling sand grains and dust whirls made it impossible to see or

breathe unless one turned one's back to the gale. Even then it was frequently necessary to stand still and shut the eyes and wait for a calmer spell, so intolerable was the eddying sand which obscured everything and so distracted the staggering climber as to make it impossible to go on. The ground was quite hot at the crater's edge, and the sulphurous odor of the vent became perceptible. At no time, however, was this at all disagreeable, as the climbing party was on the windward edge. The suddenness of the appearance of the edge was startling, and it was necessary to be cautious in approaching it as it overhung in places and might easily cave in. The outer slope changed its appearance in no respect. It was simply terminated by a precipice in the opposite direction; and while a howling gale amid opening and shutting clouds blew from the rear, in front was a steaming abyss with rapid-rising billows seen above and a yawning chasm below, showing dimly some smoking crags and clinging bowlders in the foreground. The slope extended down into steam and heat, and right and left the angular edge curved away into the sand mist. There was no lava visible, though one member of the expedition thought he caught a glimpse of something glowing through the steam. The inner cliff sloped down at an angle of from 35° to 40°, and the slope consisted of sand and broken rock fragments. Stones gathered by reaching over the edge were quite hot. About 120 feet down the inner slope appeared a number of jutting ledges at a common level, marking a bench of hard lava which had been more resistant to the caving in of the new crater. The inner face of these ledges appeared to be nearly vertical. Beyond was a steamy blank. Brownish or bluish fumes rose from cracks in the ledges. No noise could be heard above the roar of the windstorm. A little sunlight sifted through the sand clouds now and then, and during partial lulls in the wind photographs were taken, some of which produced satisfactory negatives. The curvature of the edge of the crater is quite irregular, with embayments here and there and variations in height at different places. Small cavings in and the whirl of the eddy within the rim made every now and then a purling brown vertical dust column, which moved along the edge a short distance after the fashion of the snow whirls seen on a Swiss *arête*. Indeed, the cleanly moulded sandy edge of the crater in many places resembled the overhanging scarp of the high, wind-scoured snows of the Alps.

Aneroid measurements made the summit 2,000 feet above the

Observatory and between 350 and 400 feet lower than before the eruption. It was estimated from what could be seen of the curvature of the crater that the new bowl is between one-fourth and one-half mile in diameter. The east-west diameter is much greater than the north-south, as may be plainly seen from different points of view at a distance. Therefore the new crater is somewhat elliptical. It is notched outward and downward on the northeast side, and it was the material there fallen in and abraded away which was hurled out on Ottajano. The depth of the crater is more than 150 feet — how much more could not be told.

The party remained long enough on the crest to secure specimens, photographs, and notes, and then returned down the soft sand of a depression on the northwest side of the cone. The only trace of the upper funicular railroad seen was a short stretch of half-buried track about halfway up. The appearance of the faces of the explorers when they reached the Observatory was ludicrous in the extreme. Eyes, noses, ears, and hair were plastered with gray dust, and the original color of their clothing was unrecognizable. The writer's camera, a new kodak, was no longer new.

The materials of the sand and dust are mostly ancient lavas from the walls of the vent and from the demolished cone. Professor Bassani,[1] of Naples, suggests that the peculiar sequence of fallen material — first black sand, then glassy *lapilli*, and lastly red dust — has the following significance: the black sand is probably composed of powdered black recent lava of the high conelet of 1905; the glassy *lapilli* are the sherds and droplets of the lava of the present eruption, partly involved in the explosions from the crater during the period of the greatest flow at Boscotrecase; the red dust is made of the older rusty rocks of the deeper parts of the volcano, attacked during only the last part of the eruption. This theory has not as yet been tested by microscopic investigation.

The most striking and unexpected features of the ruin wrought by lava at Boscotrecase are the absence of damage by fire in those parts of the town not invaded but adjacent to the lava, and the bowldery surface of the lava itself. It is a great field of tumbled, scoriaceous, basaltic blocks of all sizes, not a snaky tangle of congealed slag such as appears in many of the older flows. Apparently the gases emitted made the upper part of the flow very porous, and then this portion

[1] Rendiconti della R. Accademia delle Scienze F. e M. di Napoli. Fasc. 4. April, 1906.

solidified and cracked up into large blocks, while the lower part remained fluid and moved forward. This tumble of blocks seems to have acted like the moraine at the front of a glacier, and in the same manner it was shoved forward. Probably its presence at the border of the incandescent mass partly protected the adjacent buildings from fire. Another cause of immunity from fire was the masonry construction with comparatively little timber — in marked contrast with the flimsy redwood architecture which was so largely responsible for the conflagration at San Francisco. The scene at Boscotrecase is none the less desolate: villas cut in two, with one-half among the lava lumps, the other standing; the border of the lava field more than 16 feet high in places, filling railway cuts, streets, sliding into cellars, and banked against the stately ruin of the church. The stream had forked about a spur, where vineyards are, and left them untouched; it had followed lower land, where the town was, and had crushed, swallowed up, overrolled, burned, and digested everything in its immediate path, leaving a high black sweep of clinkers and broken masonry.

Seen from the mountain above, the ruins of Ottajano present a still more desolate spectacle. They appear not unlike St. Pierre in Martinique as seen from the sea. The cause of the Ottajano disaster was totally different from that at Boscotrecase. Ottajano could not possibly be reached by a lava flow from the present cone, for the high ridge of Monte Somma directly intervenes. But the distance of Ottajano from the centre of disturbance is only a quarter of a mile more than that of Boscotrecase, and what could not be reached with lava was attacked by bombardment. The volcano, probably partly dammed within by welling lavas on the Bosco side, vomited its earthy jets obliquely outward on the opposite Ottajano side. It there tore away the walls of the crater and hurled many tons of gravel and rocks on Monte Somma and beyond it. On the edge of the Monte Somma cliffs there is a huge new block of rock five feet in diameter, which was thrown a mile and landed where it now lies embedded. The ruin at Ottajano and beyond it at San Giuseppe was due to a simple, single cause — falling sand and gravel. There was no serious earthquake, fire, lightning, or wind. The sand and *lapilli* at Ottajano reach a depth of from 3 to 3½ feet on the level. The stones averaged one-third inch in diameter, but there were many as large as an apple. The roofs have caved in, carrying with them the *débris* of the walls, frequently shifting sidewise and producing puncture, rupture, or total crumbling of the loose

masonry. Vaults of sufficient thickness, arches, and dome-shaped huts were the only structures which resisted the attack. The narrow streets are piled high with the sand and fallen rubble, the footpaths through them now following a course far above the pavement. The survivors report bad air, but no asphyxiating gases. The corpses were not found in the streets, but in the houses, where death was occasioned by entombment in the ruin. The window panes were broken, especially on the side away from the volcano, indicating that there was an indraught of wind towards the mountain at the height of the eruption. Some of the flying pebbles were endowed with such high velocity from their long flight miles up, out, down, and in, that they cut clean holes through the glass.

The distinctive feature of this eruption of Vesuvius was the large amount of ash thrown out and the relatively small lava flows. The ash is believed to be mostly broken rock matter of older eruptions. Steam was the motive power, pulverizing and hurling skyward the materials of the disrupted cone. The crater suffered much in this process, its rim losing several hundred feet of height and its diameter increasing to many times its former size. With respect to these things, the present eruption of Vesuvius more resembles the Pompeian eruption than the later outbreaks characterized by lava. In magnitude the eruption of 1906 is comparable to the greater eruptions since 1631, but there is no reason to believe it of extraordinary intensity. It was unfortunate in its results, as human habitations were in the track of its discharges. Ottajano and Boscotrecase have both suffered in previous eruptions; their distance is within the danger limit. The destruction of the market in Naples by a collapsing roof was such as proper precautions might have avoided. It in no way indicated unusual violence at long range. The down-rushing cloud of steam and sand which was so conspicuous a feature in the Caribbee Islands in 1902 was not in evidence at Vesuvius, and has never been observed there since the year 79; it was possibly a feature of the great eruption of that year, when Pompeii and Herculaneum suffered.

As a disaster to human life and works, two principal agents were operative: falling gravel and flowing lava. The down-blown gases at the Observatory on the 18th of April were a third source of danger, but not at the distance of ordinary habitations. Beyond five miles no great amount of damage was done. If we add to this enumeration the blast which destroyed St. Pierre — a totally different phenomenon —

we shall have a summary of all the principal known causes of volcanic destruction — falling roofs, lava, and steam tornado. In all three cases construction is possible which will greatly protect human life. If such construction were required by law within the danger zone, volcano insurance, both of life and property, might become a less extraordinary risk. Dome and arch construction of roofs would have saved Ottajano; large cellars with iron doors were demonstrated in the West Indian eruptions as proof against the black tornado and capable of saving life; at Boscotrecase, had the town been built on the higher ground and protected by a suitable earthwork on the volcano side, there might have been no damage except to the farm lands in the valleys. Instead, the town was in the bottom land at the confluence of gulches, which guided the lava towards it.

The coincidence of the San Francisco earthquake with the Vesuvian disaster in no way indicates any terrestrial connection. Both occurred in the spring of the year. Possibly some influence of the recent rainy season in both places may have been operative. The destruction of property in both cases was occasioned by the failure of human foresight and the neglect of those concerned to study *practically* the question of forewarning. As geology is now progressing, the practical side of disaster from earth forces will never be studied as a distinct branch of science unless it is endowed as such. There is some work of this sort done in Japan, because earthquakes are there a constant menace, and in Europe seismographs are maintained at a few stations, largely by private individuals. In the United States very little has been done, although the whole Pacific coast is an earthquake and volcanic belt. It is not merely to guard against earthquakes and volcanoes that research is needed. Landslips, floods, "tidal" waves, and various marine phenomena are manifestations of earth physics affecting man which demand practical study with a view to forewarning and protection. That such means of preserving human beings and their works are worthy of study may be seen by comparison with some existing institutions. The armaments of the world are a source of protection to nations, maintained among the largest items of the public budget. Japan has lost more lives by earthquakes and their consequent tidal waves than in the whole Russian War. The United States Weather Service is maintained to study the movements of the atmosphere and thereby aid commerce, navigation, and the public safety. This service publishes a monthly bulletin and many maps. There is no like estab-

lishment anywhere in the world to study the movements of the earth and the interaction of the earth with its watery and atmospheric envelopes. Astronomical observatories are at work everywhere. Occasionally they make a practical contribution to navigation or geodesy, but almost all of their modern work is theoretical. None the less it is justly recognized as of the highest value to the progress of mankind. And yet for the devising of suitable apparatus to study our own earth, and for the maintenance of such study, there is no institution in existence. The nearest approach to such an establishment was the appropriation of money by the Carnegie Institution for a geophysical laboratory. This laboratory is doing theoretical work in pure science. But such work, following the methods of the physical and chemical laboratory, does not concern itself directly with *the earth as a laboratory*. There is needed an institution which shall be devoted to the observation and measurement of earth movements, and primarily with a view to the practical application of such studies. The practical application of first importance is the preserving of human life and property. Secondly and eventually, the accumulation of data by long observation and exploration will inevitably lead to discovery of new uses for earth energy, whereby the sources of terror and destruction now so fatal will be turned to man's account.

It is worthy of remark that the United States has now more reason than formerly to give attention to seismo-volcanic study. Porto Rico and the Panama Canal are in regions of earthquakes and earthquake waves; the whole Pacific coast from Lower California to the Alaskan Range is a field of intense seismical activity and much recent volcanism. The Aleutian chain of islands consists of active volcanoes. The Hawaiian Islands contain the most remarkable lava outpourings in the world. The Ladrones are volcanic. The Philippines, like Japan,[1] contain many active volcanoes and have frequent earthquakes. The Jesuit fathers in the Philippines have for many years maintained seismographic observatories, and the Japanese physicists and engineers lead the world in precise investigation of earth movements and earthquake construction.

[1] See Publications of the Earthquake Investigation Committee in Foreign Languages, No. 19, Tokyo, 1904. "Recent Seismological Investigations in Japan," by Baron D. Kikuchi.

WATER-TUBE BOILERS FOR MARINE SERVICE[1]

By WILLIAM LEDYARD CATHCART

The water-tube boiler has replaced the fire-tube type in all modern war vessels, from torpedo craft to battleships. While in a few constructions of comparatively recent years the fire-tube boiler is still found as part of a composite plant of both types, it is not probable that such combinations will again be installed, since the opportunities thus given for tests of both boilers, under precisely similar conditions, have confirmed the results of many previous trials of complete plants of both types and have shown the unquestionable superiority of the water-tube class for all naval uses. It seems safe to predict that eventually this history will be repeated in the merchant marine, since most of the reasons for the displacement of the fire-tube boiler from warships apply also, in greater or less degree, to all seagoing steamers.

There are two stages in the generation of steam: combustion in the furnace and transmission of heat in the boiler proper. The first of these actions is similar in all boilers; in the second there is a marked difference between the fire and water-tube types in this, that in the former the gas currents, after leaving the furnace, are subdivided within tubes which the water surrounds, while in the latter the reverse is the case, the water and steam passing through the tubes. Let us consider the effect of this difference upon

Heat Transmission through Heating Surface

The laws governing such transmission in a boiler of any class are, as a whole, but little known. The final result is the effect of several actions: convection currents and slow internal conduction in the gases, transmission by convection and exterior conduction from gases to metal, internal conduction within the latter and external conduction

[1] A lecture delivered before the Naval Architectural Society of the Massachusetts Institute of Technology.

from it to the water, and, finally, convection currents and feeble internal conduction within the mass of the water or mingled water and steam.

As to this complex series of operations, there are known only the law of heat transmission through the metal, the conductivity of water and, approximately, that of the gases. The former conductivity is, according to Lord Rayleigh, 115 times less than that of iron, while according to other investigators it is about thirty-five times greater than that of the combustion gases. While this evidence is indirect, it seems clear that heat passes with much greater difficulty from the gases to the metal than from the latter to the water — a deduction which test observations support, since they show always a much greater difference of temperature at the fire side than at the water side of the metal.

Heat Transmission in Cylindrical Boilers. — These temperature differences are vital factors in such heat transmission. Rankine[1] gives as "a rough approximation" for heat transmission through boiler heating surface a formula in which the rate of conduction varies directly as the square of the difference of temperature between the gases and the water. Later Blechynden[2] showed, from the results of his experiments, that the heat transmitted, "per degree difference between the fire and the water, is proportional to the square of the difference between the temperatures at the two sides of the plate." Rankine's formula, however, was based on the evaporation of cylindrical boilers, in which water circulation is admittedly defective, and Blechynden's experiments were conducted on a boiler which was simply a vertical, cylindrical shell. The conclusions of both have, hence, the same objections with regard to their strict application to a water-tube heating surface.

The Effect of Motion on Heat Transmission. — The state of motion of the water and gases is a further and most important factor in heat transmission. Péclet long since showed that a rapid renewal of the layers of liquid and gas, in contact with a metallic plate, was essential for efficiency in heat transmission from one medium to the other and through the plate. Later Professor Ser[3] found quantitatively the

[1] Manual of the Steam Engine, London, 1874, p. 260.

[2] Transactions Institute Naval Architects, 1894.

[3] Traité de Physique Industrielle, Paris, 1887, 1891, I, II.

effect of motion, at a uniform temperature difference, with regard to water when passed through a horizontal copper tube surrounded by a casing, the space between tube and casing being filled with steam kept at a constant temperature. Beginning with a water velocity of 0.1 metre per second, the speed was increased gradually until it became 1.1 metres. The heat transmission, rising with the speed, was 2.7 times greater, per unit of surface and of time, at the end than at the beginning.

In comparatively recent tests by Austin[1] heat from boiling oil was transmitted through the shell of a cylindrical, wrought iron boiler, open at the top and filled with water, the latter being thus boiled, both at rest and when violently stirred by a propeller. It was found that with unstirred boiling water the resistance to heat transmission at the interface between the iron and the water was equal to that of iron 1.2 to 2 cm. thick, the range being due to the state of ebullition of the water; and also that rapid stirring reduced the resistance to that of about 0.75 cm. of iron.

As to the motion of the combustion gases, Péclet,[2] in discussing the transmission of heat from one gas to another and through a metal plate, says:

"The quantity of heat which traverses the plate is determined solely by the difference of temperature of the two gases, the absorbing and emitting capacities of the two surfaces of the plate, and, above all, by the movements of the layers of gas in contact with these surfaces. We see thus that in all cases the rapid renewal of the layers of gas or liquid which touch the surfaces of the metallic plate has a very great influence on the transmission of heat, but that this condition is of much greater importance with gases than with liquids."

Again, Professor Ser — who extended the experiments previously noted to the investigation of the effect of motion on the transmission of heat to air or gases — found a marked gain in such transmission from an increase in the speed of the gas.

With regard to the relative directions of the heating and heated currents, Rankine[3] says:

"When heat is to be transferred by convection from one fluid to

[1] Mitteilungen uber Forschungsarbeiten, Verein deutscher Ingenieure, No. 7.

[2] Traité de la Chaleur, Paris, 1860, I, p. 393.

[3] Manual of the Steam Engine, London, 1874, p. 261.

another through an intervening layer of metal, the motion of the two fluid masses should, if possible, be in *opposite directions*, in order that the hottest particles of each fluid may be in communication with the hottest particles of the other and that the *minimum* difference of temperature between the adjacent particles of the two fluids may be the greatest possible."

Circulation in Water-Tube Boilers. — In all boilers the gases are in rapid motion. As to the water, however, an important difference between the fire and water-tube types is that in the former the water currents lack direction and the circulation is not only irregular with regard to the entire extent of the heating surface, but is, as a whole, relatively sluggish. In water-tube boilers, on the contrary, the circulation is controllable and depends on the tube arrangement.

Bertin [1] divides water-tube boilers, with regard to circulation, into three classes:

1. *Limited Circulation.* — These are serpentine or coil boilers, in which there is no circulation except that necessary to replace the water evaporated. The generating coils receive the feed water at one end and discharge the steam at the other.

2. *Free Circulation.* — The chief characteristic of this class is the presence of a vertical, flat water space at the front and another at the back of the boiler, the two connected by horizontal or slightly inclined tubes, and each joined at the top to a steam and water drum. The water passes from the drum through one space and the tubes and then returns, partly as steam, through the other water space to the drum. The circulation is much more rapid than in the previous case, and the steam escapes from the heating surface much more freely.

3. *Accelerated Circulation.* — In this class the main feature is the direction of the generating tubes, which connect an upper steam drum and a lower water drum, and are set as nearly vertical as possible. Large downtake tubes return the water from the former drum to the latter. Maximum rapidity of circulation is attainable in this form.

Of boilers designed for general marine service, the Belleville, the D'Allest, and the Yarrow may be cited as examples of the first, second, and third classes, respectively. In general, the circulation should be sufficiently rapid to secure full efficiency in heat trans-

[1] Marine Boilers, London, 1905, p. 34.

mission and to sweep away the steam from the heating surface. For use at sea the boiler should have a circulation which is assured and positive in direction under all conditions of pitching and rolling. A circulation which is sluggish, spasmodic, or capable of temporary reversal in a seaway is liable to cause burned tubes.

Factors of Circulation. — The forces acting to produce water circulation are essentially the same in all water-tube boilers of "free" circulation having inclined tubes, and also in those of "accelerated" circulation. The Babcock and Wilcox marine boiler has some of the characteristics of both of these classes, as defined by Bertin, although its tube inclination is somewhat greater than that laid down for "free" circulation; it has no general "water spaces," but independent headers for each element, and the centre of its circulating tubes is at the water level in the drum.

As shown in Figure 1, the feed water enters the steam and water drum at the top and front of the boiler. It then passes downward through the front "header," which is essentially a corrugated box of rectangular section. From this header it ascends through the generating tubes, which are inclined usually at an angle of about 15° with the horizontal. In its passage through these tubes it receives the greater portion of its heat, so that, partly as steam, it traverses the rear header — which is similar to that at the front — and the horizontal circulating tubes in its return to the drum. The normal water level is the plane of the centres of the circulating tubes and drum. The steam leaves the latter through a dry pipe at the top.

The factors[1] which combine to produce circulation in such a circuit — which includes two approximately vertical sections, one (from the water level in the drum downward) of solid water, the other, during rapid generation, composed of water and steam — are:

1. The reduction in density of the water in the ascending column from the rise in temperature due to its passage through the generating tubes. This effect, small in any event, is still further reduced by rapid circulation, which acts to keep all water in the boiler at or near the temperature of the steam. Hence the effective action of this reduced density is practically limited to the interval between the lighting of the fires and the formation of steam.

2. The difference between the densities of the descending and

[1] For discussion see Marine Boilers, Bertin, London, 1905, p. 400.

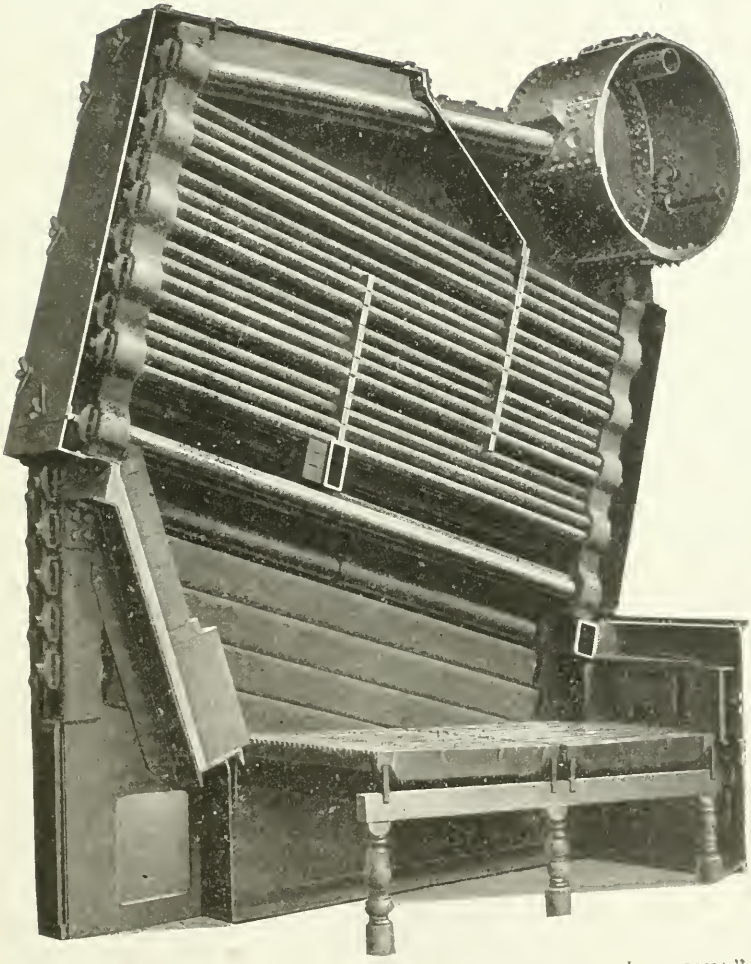


FIG. 1.—SECTION OF BABCOCK AND WILCOX BOILER OF "LOUISIANA"

ascending columns, due to the former being composed of solid water, the latter of a mixture of water and steam. For example, if the discharge from the circulating tubes is three parts of steam and two of water, the circulating force at the top of the descending column would amount to three-fifths of the specific gravity of an equal column of solid water, less, of course, the loss of head due to friction, bends, etc.

Speed of Circulation. — General indications as to the variations in the speed of circulation in the successive tube rows of boilers of "free circulation," as defined by Bertin, are given in the report of a trial by Fuchs[1] of such a boiler having eight rows of tubes, with a superheater fitted above the middle of the top row. The steam pressure was 11.9 kilograms per square centimetre, absolute, and the evaporation 24.85 kilograms per hour per square metre of heating surface. The velocity of the water was measured by the speed of small propellers inserted in the tubes. The water velocities, in metres per second, were: in the first (lowest) row, 0.98; in the fourth row, 0.328; in the eighth (top) row, 0.033.

Tube Inclination and Evaporation. — Watt[2] experimented upon a small model boiler so constructed that the tube inclination could be changed gradually from the horizontal to the vertical. The evaporation per unit of surface was found to be highest at a tube inclination of 10° with the horizontal; at 15° it was 97 per cent. of this maximum; at 90°, 59 per cent.; and when horizontal, 88 per cent. Other things equal, evaporation depends less upon water circulation, providing the latter is fair, than upon the manner in which the gas currents impinge upon the tubes and circulate among them. Watt's results, therefore, apply specifically only to the conditions of his tests.

Relative Efficiency of Heating Surface. — Watt also concluded from further tests "that practically 60 per cent. of all the steam generated in any water-tube boiler, with tubes at any angle, is generated in the first or nearest row of tubes to the fire" — a result due mainly to radiant heat and the fact that the gases have their highest temperature and velocity when they meet this tube row.

Practical Limits of Water Circulation. — In the progress of the water-tube boiler primary importance was at one time given generally

[1] Generator-Kraftgas- und Dampfkessel-Betrieb, Berlin, 1905, p. 70.

[2] Transactions of the Institute of Naval Architects, 1896.

to very high speeds of circulation. This view is still held by some of the foremost authorities. For example, M. Bertin [1] says:

"Everything possible should be done to assist the circulation by encouraging all that tends to produce steam, removing, as far as possible, any causes tending to reduce the circulation, as the efficiency of a boiler increases with the speed of the circulation."

The opposing view is indicated by the following:

"It is claimed by some manufacturers that the rapid circulation of water in their boilers tends to make them more economical than others. We have as yet, however, to find any proof that increased circulation of water, beyond that usually found in any boiler, will give increased economy. We know that increased rate of flow of air over radiating surfaces increases the amount of heat transmitted through the surface, but this is because by the increased circulation cold air is continually brought in contact with the surface, making an increased difference in temperature on the two sides, which causes increased transmission. But by increasing the rapidity of circulation in a steam boiler we cannot vary the difference of temperature to any appreciable extent, for the water and the steam in the boiler are at about the same temperature throughout." [2]

As to this, it may be noted that the experiments of Professor Ser, previously quoted, which showed a marked increase in heat transmission with the rise in the velocity of the water, were conducted at a practically constant temperature difference between the heating and heated media. Further, the tests of Austin, also cited, indicate that — also at a practically constant temperature difference — motion of the water reduces the resistance to heat transmission at the interface of the metal and water.

Increase in temperature difference gives, *per se*, a rise in heat transmission; but if the results of these two series of experiments be accepted it is clear that at a constant temperature difference a greater velocity of the water augments the rate of heat transmission.

Boiler economy is, however, dependent, not only upon the efficiency of heat transmission to the water, but also upon that of heat transmission from the gases. Granting that a greater velocity of the water makes possible a higher rate of heat transmission to it, there must be

[1] Marine Boilers, London, 1905, p. 417.

[2] Steam Boiler Economy, Kent, New York, 1904, p. 299.

secured, also, a proportionate rise in heat transmission from the gases in order to obtain an increase in boiler efficiency corresponding with that in water speed.

In discussing these conditions Professor John Perry, F.R.S., said[1]:

"One small tube conveying hot gases, dragged through at an enormous velocity, and a concentric tube conveying water in the opposite direction at great velocity — they had in that combination a method of giving up heat which was fifty times as great as what occurred in an equal amount of heating surface in the best existing boilers."

This combination would be, theoretically, most advantageous, especially in its control of the direction and in its minute subdivision of the gas currents, which subdivision would act to offset the low conductivity of the gases. It represents, in effect, the views of Péclet and Rankine carried to what would be a logical but, at present, impracticable extreme.

The difficulty of effective abstraction of heat from the gases is the limitation which prevents the increase in efficiency otherwise possible by extreme speeds in water circulation. Practically, therefore, all that is necessary is a circulation which is sufficient to sweep away bubbles of steam from the heating surface, thus preventing overheating, which is active enough to keep all water in the boiler at about the same temperature, and which is absolutely "free," so that when required the boiler may be forced to the limit fixed by its heating surface, combustion space, and baffling.

In boilers for land service a circulation beyond the limit otherwise necessary is sometimes of value in using feed water containing a considerable amount of substances tending to form scale or other incrustation. The greater scouring action of the water with more rapid circulation acts to prevent the deposition of such substances, especially when the boiler is below its normal load.

Heat Transmission from the Gases. — In a marine water-tube boiler whose circulation is either "accelerated" or sufficiently "free," the heat transmission at the water side of the heating surface may be considered as sufficiently rapid to transfer at once all heat received by the metal. Hence, other things equal — as to the rate of combustion per square foot of heating surface, the condition and relative value of the latter, the completeness of combustion, and the losses from radiation

[1] Transactions of the Institution of Engineers and Shipbuilders in Scotland, XLII.

and air leaks in the casing — it is evident that in practice the relative efficiency of such boilers depends upon that of heat transmission from the gases, since this determines the temperature of the latter at exit to the chimney.

The principal conditions affecting the amount of heat transmitted from the gases to the heating surface are:

1. The low conductivity of the gases, which, as stated, is about thirty-five times less than that of water. The condition can be met most effectively only by splitting the gas current into thin sheets in its flow past the heating surfaces.

2. The duration of the contact of the gases and heating surface. This at best is very brief. In some cases the gases pass through the boiler in three-fourths of a second. This condition shows the advantage of baffling to form a circuitous route for the gases in order to increase the distance traveled by them in contact with heating surface.

Speed and Direction of the Gases. — The principles relating to these factors in heat transmission have been noted previously. Rankine's dictum as to the opposing directions of the currents of gas and water, while theoretically correct, would be of full value in practice only if applied to sheets of gas sufficiently thin to overcome appreciably, during the brief duration of contact, the low conductivity of the gases.

In the water-tube boiler these sheets in passing between the tubes are relatively thick, and the gases move at very high velocity in the path of least resistance. Hence to remedy feeble conductivity and to give convection as full action as possible the gas currents should be opposed and broken by impinging, preferably at right angles, upon staggered tubes.

Baffling. — In water-tube boilers the total space for the passage of the gases from furnace to uptake is, as a rule, relatively large as compared with the furnace volume. Hence, under forced draught especially, the gas currents, if not directed by baffling, will take the shortest way to the smoke pipe, thus meeting only a part of the heating surface and leaving the remainder ineffective. In many of the earlier water-tube boilers the gases were practically shunted up the smoke pipe, so that the latter, even with natural draught, was heated to a dull red at the base, thus increasing the draught and reducing efficiency by drawing in an excess of air.

In order to conduct the gases over the entire heating surface and to increase their travel and duration of contact, a system of baffling is

absolutely essential in every water-tube boiler. In some boilers having "accelerated" circulation, and hence approximately vertical tubes, the latter, in the row next the furnace and in that next the casing, are so set as to touch tangentially throughout the lengths of these two rows, thus forming "water walls" which enclose the gases in their passage horizontally between the remaining rows. In other boilers of similar circulation a perforated plate is set on the outer row of tubes, which plate by offering some resistance to the flow of the gases acts to give the latter a more equal distribution. In the Babcock and Wilcox boiler baffling is effected by sheet-metal partitions set perpendicularly to the tubes, which partitions divide the total space into three approximately equal and consecutive passages.

Some water-tube boilers cannot be baffled at all without destroying the special characteristics which are their chief reason for existence. As a result they are most wasteful under forced draught. Baffling should in any case be so designed as to offer the least possible resistance to the flow of the gases, since such resistance increases the power required, under forced draught, from the blowers.

Summary. — With regard to heat transmission, any water-tube boiler having a circulation sufficiently "free" or "accelerated" is superior to the marine cylindrical type in so far as the water side of the heating surface is concerned, owing to the subdivision of the water within tubes and the active and sustained circulation. As to the gases, however, the reverse is the case in general, since in the cylindrical boiler the total volume of the gases is not only subdivided in tubes, but retarders may be used, as in the Howden system, to combat low conductivity and increase convectional action. Whitham,[1] in trials of a horizontal fire-tube boiler, found that these appliances gave an economic advantage when the boiler was pressed, varying in his tests from 3 to 18 per cent.

Hence in water-tube boilers generally the heating surface is not, as a whole, as effective as that of the cylindrical type, although portions of it, where the gas circulation is most favorable, are unsurpassed in efficiency. A thorough system of baffling, however, in such boilers as are fitted for it overcomes largely the difficulties with regard to the gases.

These conclusions apply only to clean heating surface. Some

[1] Transactions of the American Society of Mechanical Engineers, XVII.

water-tube boilers with straight tubes are so constructed that the water side of the heating surface is fully accessible, while it is possible, also, to keep the outer side of the tubes almost wholly free from soot while running and to cleanse it thoroughly when the boiler is out of use. In such cases the efficiency of the heating surface as to cleanliness can be much more readily maintained than in the cylindrical type.

Requirements of Water-Tube Boilers for General Marine Service

"Express" Boilers. — Water-tube boilers for marine service may be divided generally into the "small-tube" and "large-tube" forms. The former class — the "express" type — is that used in torpedo craft and similar vessels where extreme speed for brief periods is the principal consideration, and hence where minimum weight and the ability to stand high forcing, without special regard to economy, are essential. These objects are attained by providing an excess amount of heating surface in thin tubes of small diameter, closely spaced and arranged for "accelerated" circulation; by carrying the least possible amount of contained water; and by making the casing and fittings relatively very light.

"Large-Tube" Boilers. — The "large-tube" boiler, on the other hand, is intended for general service in battleships, cruisers, and merchant steamers. Since such vessels must make long voyages in all weathers, and are at times far from a repair base, boilers for this service should have qualities of endurance in various respects which are not required from the "small-tube" type. Hence they have more contained water, are less sensitive in steaming, and are of stronger build and greater weight than "small-tube" boilers. "Large" tubes may be described generally as those of 2 inches in diameter and upward, although this dimension is not wholly accurate for differentiating these two classes.

Requirements. — The following requirements should be considered in comparing water-tube boilers designed for general service at sea:

1. *Efficiency.* — The boiler should have such combustion space, heating surface, water circulation, and baffling as will give it high efficiency at its usual rate of steaming, with, in war vessels, no serious reduction in that efficiency at the limit of reasonable forcing. This

limit, under service conditions in the United States Navy, appears to be a consumption of about 40 pounds of coal per square foot of grate surface.

2. *Sustained Efficiency.* — For sustained efficiency the tube system should be so arranged that both sides of the heating surface can be kept clean. Despite all precautions some scale is sure to be deposited, owing to leaky condensers, defective valves, or an occasional unauthorized dose of salt feed when low water is feared. It is also impossible to keep the tubes entirely free from oil, since, although there may be no lubrication of the main cylinders, it will enter through the exhaust from dynamos, pumps, and other auxiliaries. Sediment may form also from oil and rust or the use of muddy water.

For these reasons the interior of the tubes should be readily accessible, both for inspection and the use of scaling cutters, while ample means should be provided for blowing the soot from their exterior while under way and for thoroughly cleaning the boiler when out of use.

3. *Size of Units.* — The boiler should be capable of construction in the form of single units of large power. A large number of small boilers means much added complication in piping, valves, fittings, and pumps, with a corresponding increase in the cost of maintenance and the care required in operation.

4. *Sectional Construction.* — Sectional construction of the tube system, *i. e.*, the division of the heating surface into a number of similar elements, each (in action and fitting) independent of the others, is an advantage of much importance in obviating all strains due to unequal expansion and contraction and in making possible the erection of the boiler in sections on the vessel, thus avoiding all cutting of the decks in reboilering.

5. *Weight.* — Weight saving in both boiler and contained water is an inherent advantage of the water-tube system as compared with the cylindrical type. This advantage should not, however, be pressed to extremes in boilers designed for general service at sea. It is false economy in such cases to limit the area and thickness of the heating surface, to build a light casing which will warp and leak, giving rise to large heat losses, and to have so small a volume of contained water that incessant vigilance is required to maintain its level in the gauge glass and to prevent the burning of tubes. The added weight required to give full combustion space, ample heating surface, a reasonable

amount of contained water, and an adequate casing will in service be much more than offset by the reduction in the weight of coal required for long runs and in that of boilers temporarily disabled and carried as useless freight.

6. *Repairs.* — In warships frequently, and in all vessels at times,

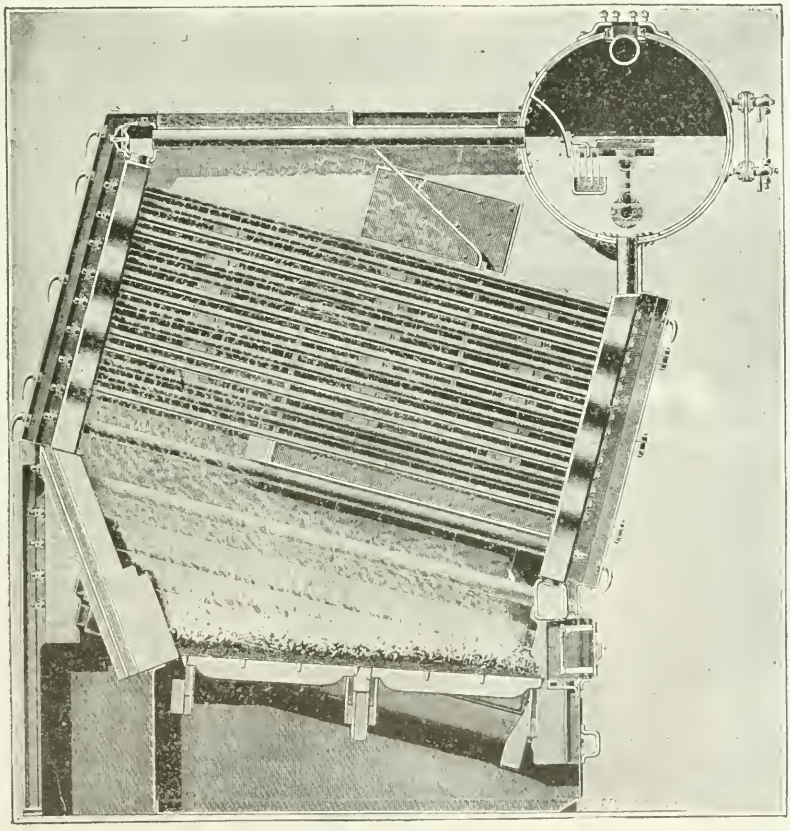


FIG. 2. — "CINCINNATI'S" BOILER. SECTION SHOWING PATH OF GASES

repairs must be made by the ship's force, unaided by the facilities of a repair base. Hence, so far as is possible, the boiler should be so designed as to enable this work to be done readily and quickly. The pressure parts should be accessible, simple, and uniform. Varied forms of tubes, unusual joints, and special fittings of any kind increase, not only the difficulty of repairs, but the number of spare parts to be carried.

Status of the Marine Water-Tube Boiler

The water-tube boiler has in marine service a long history. Fifty years ago the Belleville boiler of that day was installed in the French war vessel *Biche*. It was not until 1888, however, that French naval authorities, the leaders in this advance, took radical action in deciding to replace the cylindrical boiler with those of the Belleville and D'Allest type. From the latter date onward the water-tube boiler has won its way in a progress which has been attended by the production of a large number of designs and by a volume of controversy which, in extent and duration, is probably without equal in the history of marine engineering.

In the course of time the vexed question as to the relative advantages, for general marine service, of many widely differing forms seems to have narrowed down to the consideration of comparatively a few leading boilers. The main principles governing the action and efficiency of these boilers as a class have been discussed. The application of these principles, and hence the status of the marine water-tube boiler, in a practical and successful design will be, perhaps, best understood by the consideration of one of its widely accepted forms.

For this purpose the Babcock and Wilcox marine boiler has some special advantages in the fact that complete data are available. Since 1899 it has been installed in or specified for thirty-seven of our national vessels, from battleships to gunboats. In the papers of United States naval officers on duty as inspectors or as members of trial boards, as published in the *Journal of the American Society of Naval Engineers*, there are given the very full data on which are based the following description of the construction and analysis of the performance of this boiler. The lecturer desires to acknowledge his indebtedness to the editor of the *Journal* and to the Babcock and Wilcox Company for the use of this information and the accompanying illustrations.

The Babcock and Wilcox Marine Boiler: Details of Construction

Modifications for Marine Service. — The marine and the usual land form of this boiler differ in some important respects, the purpose of the changes in the latter form to fit it for sea service being to provide, relatively, much larger areas of grate and heating surface in the same

space. Thus (Figures 2, 4) the furnace in the marine form extends beneath practically the entire length of the tubes, giving the maximum horizontal area of grate, and the diameter of the tubes, excepting in the lower row and at the top of the furnace sides, has been reduced to 2 inches to provide ample heating surface. The steam and water drum is also set transversely to the tubes and at the top and lower end of the bank, thus lessening the height of the boiler; and the firing end is beneath this drum, making the volume of the furnace largest at the rear, where the need of combustion space is greatest. The setting of the land boiler is, of course, replaced by a casing. These changes are in some respects a development of a compact design built originally for land service.

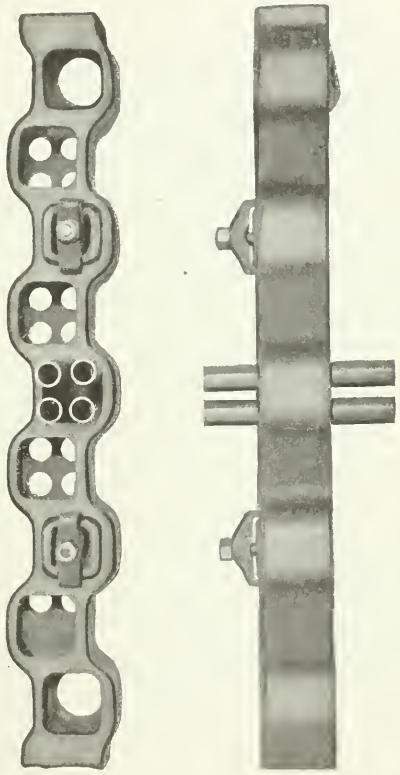


Fig. 3. — Forged Steel Header, Showing Hand-Hole Plates

Sectional Elements. — The tube heating surface is divided into sectional elements, each of the latter being composed of vertically staggered groups — four tubes to a group and seven or eight groups to a pair of headers — of 2-inch tubes, with a 4-inch tube at the bottom, all straight. The tubes are inclined usually at an angle of 15° with the horizontal, and are fixed at each end in boxes or headers (Figure 3), the latter being rectangular in section, perpendicular to the tube axes, corrugated vertically to stagger the tube groups, and closed in front of each group and of each 4-inch tube by a hand-hole plate.

The top of each rear header is connected with the steam and water drum by a horizontal circulating tube 4 inches in diameter. Each front header is joined to this drum and to a horizontal cross box, or "mud drum," by nipples of 4-inch tube. In the end elements, which form the sides of the boiler down to the furnace top (Figures 4, 5), the tubes in the outer corrugations are left out in order to give an

approximately straight tube service against which to build the side casing.

All tubes are of seamless, cold-drawn steel. The 2 and 4-inch tubes are 8 and 6 B. W. G., respectively, in thickness. The headers are forged from open-hearth steel plate ½ inch thick. The hand-hole plates are of wrought steel; the joint is made on the inside of the header by a thin gasket between faced seats. Expanded joints are used for all tubes and nipples.

Cross Box. — The cross box, or mud drum, forms a blow-off collector through which the boiler may be drained. It is forged from ⅝-inch, open-hearth steel plate, is 6 inches square in section, and has hand-holes in the front. It is connected with the front headers and the corner boxes by 4-inch nipples.

Furnace Sides. — The water sides (Figures 2, 4, 5) of the furnace are each composed of four forged steel boxes, 6 inches square in section, and one 4-inch tube, all of which are parallel to the main tubes and enter two vertical corner boxes, one at the front and one at the rear of each side. When the boiler has more than twenty-three sectional elements there are three water sides — two at the furnace sides and one near its middle, the latter water side being connected with a pair of vertical middle boxes similar to the corner boxes.

Thus in each of the boilers of the battleship *Nebraska* there are thirty sections and three water sides. The middle water side divides the grate into two sections, 8 feet 3¼ inches and 7 feet 8¼ inches in width, respectively. The length of the grate is 7 feet. The water sides and the middle and corner boxes are connected by 4-inch nipples with expanded joints.

Corner and Middle Boxes. — The four corner boxes and the two middle boxes (if used) are forged of the same steel as the cross box; they are 7 inches square outside, ⅝ inch thick, and have hand-holes in front. They are connected with the water sides, the cross box, and the headers immediately above them by 4-inch nipples with expanded joints, and by the latter with the 4-inch tube of the water side.

A 1-inch plate welded in forms the top of each box, and the bottom is closed in the same way by a 1¼-inch plate. From the latter, and made integral with it, a 2-inch stud projects, which fits into a hole in the foundation and is secured by a nut. The corner and middle boxes thus form the supports of the boiler. The plane of their tops is at an angle of 15° with the horizontal.

Drum. — The steam and water drum (Figures 2, 4) provides steam space and water capacity. It is cylindrical with "dished" heads, is 42 inches in diameter inside, and has a length sufficient for the connection of the extreme headers, or practically that of the width of the boiler. Its shell is made of two plates, each the length of the drum, one of such width as to extend through three-fourths of the circumfer-

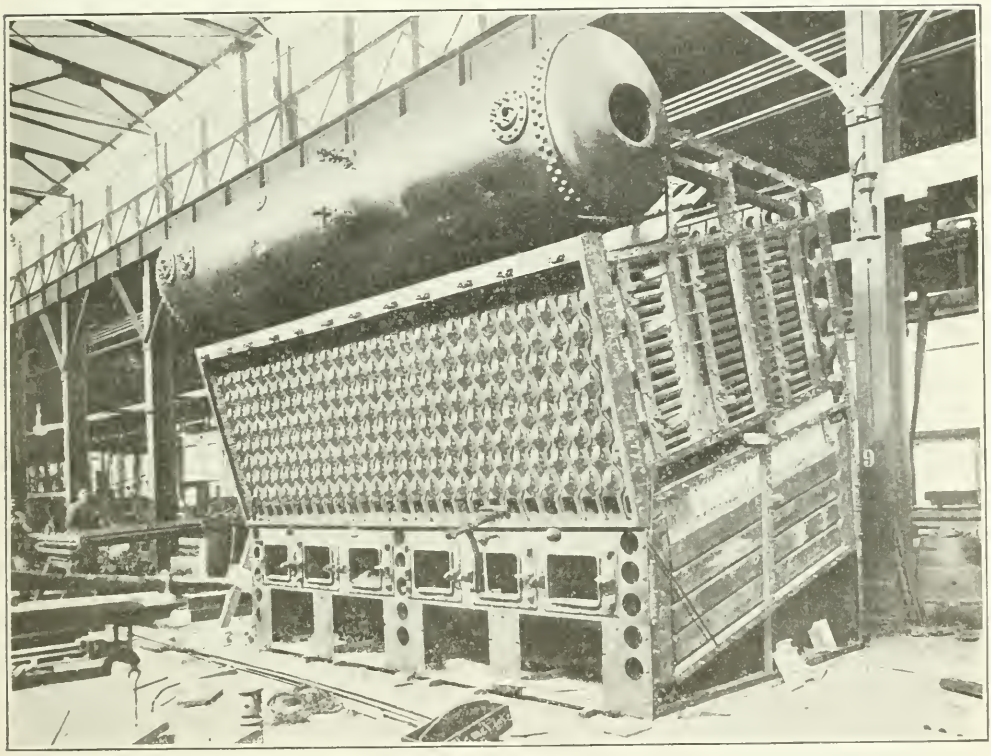


FIG. 4. — ASSEMBLING THE BOILER; READY FOR FIRE TILES AND CASINGS

ence, the other covering the remaining one-fourth. The longitudinal joints are made with double butt straps.

These joints are thus 90° of arc apart, and the drum is so set that the centre line of one coincides with that of the upper nipples of the front headers, while the centre line of the other is identical with that of the circulation tubes which connect the drum and the rear headers. The holes for the tubes and nipples are drilled $4\frac{1}{32}$ inches diameter through the straps and are punched to a diameter of $4\frac{1}{4}$ inches through

the abutting edges of the shell plates. Hence the tubes and nipples when expanded bear only on the metal of the straps, and bulge out slightly in the annular space remaining in the holes in the plates. This construction makes an exceptionally strong joint.

The drumheads are pressed from flat, circular plates 52 inches in diameter. The radius of the spherical "bump," or "dishing," is the same as the drum diameter, 42 inches. Manholes with reënforcing rings are made in the centre of the heads, and the latter are riveted to the shell with double zigzag seams. The butt straps of the shell are held by six rows of rivets, four of which pass through both straps. The thickness of the shell plates and straps is $\frac{21}{32}$ inch; that of the drum head is $\frac{3}{4}$ inch.

The steam openings in the drum are: one for main and auxiliary steam pipes, one for the safety valves, and one for a fitting to which are attached the steam gauge, sentinel valves, and air cock. The water openings are: one for main feed, one for auxiliary feed, one for surface blow, two for each of the two water gauges, and three for the test cocks.

The interior fittings of the drum are: semicircular swash plates to retard the movement of the water when the ship is rolling; perforated baskets for zinc; curved, hinged, and latched baffle plates over the mouths of the circulating tubes; two brass feed pipes, perforated in the upper half, set parallel to, but below, the axis of the drum; a brass dry pipe, perforated in the upper half, connecting the two steam openings; and a steel scum pan of flat, rectangular shape.

Baffles. — The row of 4-inch tubes immediately above the fire is covered with fire brick fitted to the tubes for a distance of about two-thirds of their length from the front, thus roofing the furnace to that extent. A similar baffle is laid horizontally from rear to front on the 4-inch circulating tubes for about one-half their length. From the end of the furnace top a plate baffle extends upward. The gases pass upward from the back of the furnace over the top of this baffle, and then flow downward between it and a similar baffle depending from the horizontal baffle at the top. After passing the lower edge of this second baffle the flames again turn upward, through the tubes and an opening in the top casing back of the drum, to the uptake. The upright baffles thus fall at points which are at about one-third the length of the tubes from their ends, dividing the tube surface into three approximately equal parts.

Supports and Foundations. — The weight of the front ends of the sectional elements is taken by the nipples connecting the front headers with the steam and water drum. The rear ends of the sections are supported by an I-beam resting on brackets bolted to the rear corner boxes. The side and middle sections are stepped into the corner and middle boxes.

The steam and water drum is supported at each end and at the middle by sleeves fitting around the nipples at these points and resting on the tops of the front headers. The drum thus serves as

FIG. 5. — VIEW OF FURNACE FROM BRIDGEWALL, SHOWING ABSENCE OF FIRE BRICK IN SIDE WALLS AND BETWEEN FIRE DOORS

a beam to increase the stiffness of the boiler and to support the front ends of the sections.

The corner and middle boxes rest on chair pieces in the foundations, and each is held in place by a 2-inch stud and nut. The foundations are built up of two 8-inch channel irons, one of which, laid horizontally, flanges upward, forms the base; and the other, set at an angle of 15° with the horizontal, and with the flanges down, forms the top. To the inside flanges of these channel irons there is riveted a ¼-inch side plate. Each of the two chair pieces is connected to the foundation base by rivets, to the side plate by two angle irons, and to the top by a steel angle. In each foot of each saddle piece

there is a 1¾-inch hole through which the holding-down bolts pass. In the top of each saddle piece there is a hole 2½ inches in diameter, through which the lug in the bottom of the corner box passes; this lug holds the boiler to the foundation. There are three of these foundation pieces in all boilers having middle boxes.

Casing. — The entire boiler, except the drum, is enclosed in an air-tight casing (Figure 7), consisting — from the inside outward — of light fire tiles, ¼-inch asbestos mill board, and 2-inch block magnesia, backed with galvanized steel plate ¼ inch thick. The fire tiles, as shown in Figure 6 by the interior of the cleaning doors, are shaped to fit the sides of the tubes and the spaces between them. All cracks between headers, side boxes, etc., are calked with rope asbestos. The outside plating is held in place by edge straps bolted to the casing frame, and is thus readily removable. The latter is built of angles, and is secured to the boiler foundation by straps held in place by studs and nuts, the studs being screwed into the flanges of the angles forming the framework. The removal of the casing to expose the tubes and baffles is the work of a few minutes.

Cleaning Openings. — As shown in Figure 6, there are three upright doors in the side of the casing, one opposite each division of the heating surface formed by the upright baffles. These three doors are swung on side hinges and may readily be opened. Below them there are two narrow horizontal doors (Figure 7) held in place by latches, which enable the soot to be cleaned from the baffle forming the furnace top, and above them and just back of the drum there is another latched door (Figure 6), which gives access to the space above the inclined tubes.

These six doors provide ample means of cleaning the heating surfaces when the boiler is not in use if sufficient room be left at the side of the boiler to permit the use of the soot hoe and tube brushes. The soot may be also almost entirely removed from the tubes while under way by means of an air jet or steam lance inserted through the five (or seven) small openings made on the vertical centre line of each of the three main "dusting" doors. These holes are closed by a sliding shutter; they serve also as peepholes to observe the extent of the flame.

Fire Front and Doors. — The fire fronts of the boiler are of wrought steel and contain fire and ash doors. The fire doors are made of ½-inch steel plate, accurately fitted to a flanged door frame of the

same material; these doors are lined with cast iron. The ash doors are also of wrought steel and the ash pans of galvanized steel.

Tube Doors. — The front and rear tube doors are made of steel plate riveted to a bar steel frame and lined with non-conducting material, backed by sheet copper secured by rivets. The frames of the rear tube doors are attached to the I-beam which supports the rear ends of the sections.

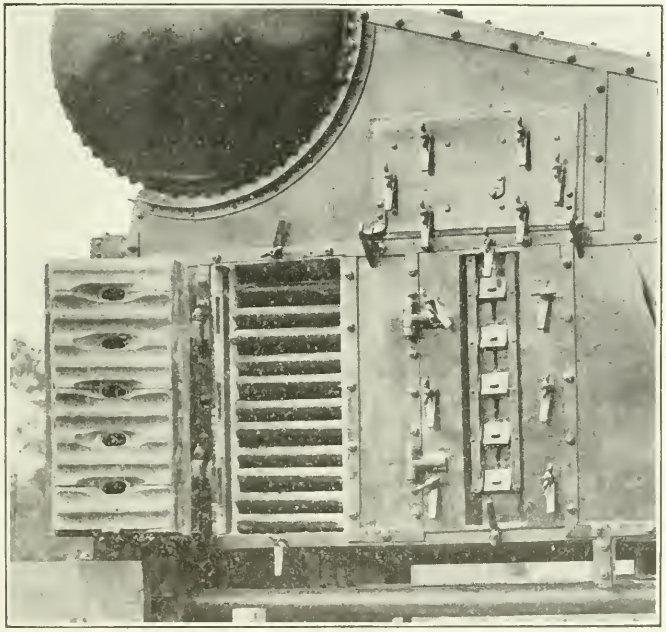


FIG. 6. — CLEANING DOORS

Centre of Gravity of Boiler. — The centre of gravity of the boiler lies, approximately, on a horizontal line passing through the intersection of two diagonal lines, one drawn on the side elevation of the boiler from the centre of the drum to the lowest point of the foundation at the back, and the other from the highest point of the rear header to the base of the foundation at the front. The centre of gravity is thus about 6 feet above the base. When the boiler is filled this distance is increased slightly.

Characteristics and Construction

Sectional Construction. — The Babcock and Wilcox boiler is of sectional construction, the tube heating surface being divided into elements, each independent of the others. Each element is composed of its generating tubes, one front and one rear header, and a circulating tube. Such a system gives freedom for unequal expansion in rapid steam raising and for contraction due to sudden cooling. All flat-stayed surfaces are dispensed with by the use of the headers.

A marked advantage of the sectional system is that the boiler may be assembled on shipboard, thus obviating any cutting of the decks in reboilering. At the outbreak of the Spanish-American War three of the old single-turreted monitors were thus reboilered, the parts being passed below through the 7-foot armored smoke pipes. Two of the vessels were ready for steam in thirty days and the third in forty-two days after the work was ordered.

Size of Units. — An objection frequently urged in the past against the water-tube boiler in general was that the size of its units was smaller, and hence their number for the same total power greater, than those of the marine cylindrical boiler, with a consequent increase in the number of valves and fittings and in the extent and complexity of the piping.

Such objections no longer apply to this boiler, since its system of construction makes possible as great an increase in width as is permitted by the efficient use of the lance from the sides in blowing soot from the tubes. In the table below are given average data from the *Alabama* class of battleships — the last vessels built with cylindrical boilers for the United States Navy — and similar data from the most recent trial of a battleship fitted with the Babcock and Wilcox boiler.

	I. H. P.	Boilers.	H. P. per unit.
Battleship *Alabama*	12,291	8 S. E. cyl.	1,536
Battleship *Louisiana* . . .	21,350	12. B. W.	1,779

Weight Saving. — The economy in weight from the use of water-tube boilers lies in both that of the boiler and that of its contained water. With regard to the boiler (*dry*) the following average data refer to the *Alabama* class, as built, and their total I. H. P. on con-

tract trials, and to the battleship *Nebraska* (12 B. W.), the power being the designed I. H. P. and the weight that estimated from the weight of one boiler as built.

	I. H. P.	Boilers: Weight (Dry), Pounds.	
		Total.	Per I. H. P.
Battleship *Alabama*	12,291	905,525	73.67
Battleship *Nebraska* . . .	19,000	1,165,596	61.35

There is thus a weight saving in the boilers (dry) of 16.9 per cent., based on the weight per I. H. P.

The comparison, including the weight of the contained water, is:

	Weights, Pounds.		
	Water, total.	Water per I. H. P.	Boilers (wet) per I. H. P.
Alabama	345,342	28.09	101.76
Nebraska	234,384	12.34	73.69

which shows a saving per I. H. P. of 56.1 per cent. in the weight of contained water, and of 27.6 per cent. in that of boilers and water combined.

The comparison, with regard to grate and heating surface, is for the weights of boilers and water combined:

	Boilers, Wet. Pounds per Square Foot of	
	Grate surface.	Heating surface.
Alabama	1,855	57.5
Nebraska	1,044	24.9

The weight of contained water is that of the amount at 4 inches above the highest heating surface in the cylindrical boiler and at the level of the centre of the drum in the Babcock and Wilcox boiler. The *Nebraska* weights were found with the water at 62° F.

The working pressure of these boilers is for the *Alabama* class

180 pounds gauge and for the *Nebraska* class 275 pounds gauge. Since the advanced pressure gives greater steam economy and reduces the machinery weights per I. H. P., it is evident that a just comparison between the cylindrical and water-tube types is that at the working pressure which the latter makes practicable. The following data — pre-

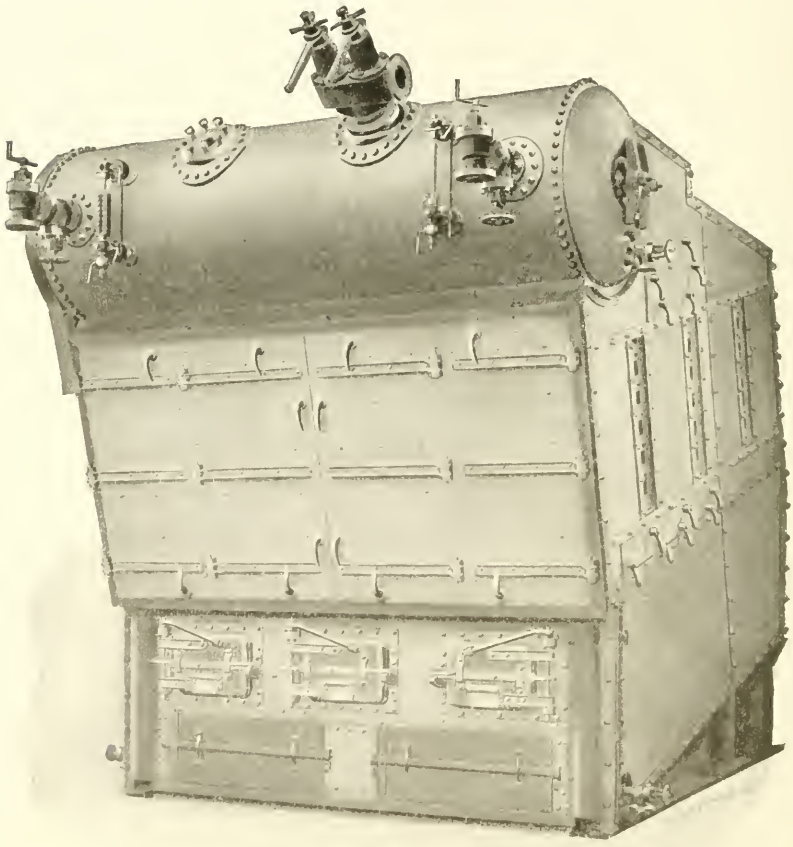


Fig. 7. — Boiler Complete, Showing Casing

pared some years ago at the Bureau of Steam Engineering, United States Navy — show this relation with regard to a proposed naval installation of 16,500 I. H. P. at 250 pounds working pressure. The comparison was made between a plant consisting of six double-ended and two single-ended Scotch boilers and one of twelve Babcock and Wilcox boilers.

	Cylindrical.	Babcock and Wilcox.
Steam pressure, gauge, pounds	250	250
Weights, boilers and fittings, tons	739	462
Weights, water in boilers, tons	252	105
Weights, boilers and water, tons	991	567
Weights, all machinery, including stores, tons	2,045	1,630

It will be seen that the use of cylindrical boilers would have increased the weights of boilers and water 74.8 per cent. and the total machinery weights 25.5 per cent. However, the cylindrical boiler at that pressure was a practical impossibility. The boilers estimated upon for this comparison were 15 feet $5\frac{1}{8}$ inches in diameter, with shell sheets $1\frac{5}{16}\frac{9}{4}$ inches thick, braces 3 inches in diameter, and furnaces but 2 feet 9 inches in diameter. Were the cylindrical boiler the only reliance, the road to higher working pressures would be blocked.

Floor Space. — The inclination of the tubes of the Babcock and Wilcox boiler is sufficient to assure a positive circulation under all conditions of rolling and pitching. Hence it may be installed with its tubes either fore and aft or athwartship. The latter method of installation — which is impossible for boilers of feeble or uncertain circulation — is that used with the Babcock and Wilcox boilers on the United States cruisers *Chicago*, *Atlanta*, *Cincinnati*, and *Raleigh*, and on forty-five merchant steamers on the Great Lakes. Since its form is approximately rectangular throughout, it is well fitted for utilization of a limited space.

The ratio of floor space (horizontal projection) to grate areas is, in general, about 1.9, as compared with 2.1 for the cylindrical boiler. With the larger units this ratio is somewhat more favorable to the Babcock and Wilcox boiler. Thus the data for the protected cruiser *Charleston* are:

I. H. P., all machinery	27,506.0
Boilers	16 B. W.
H. P. per boiler unit	1,719.0
Floor space, one boiler, square feet	138.2
Grate surface, one boiler, square feet	87.5
Floor space ÷ grate surface	1.58

The extreme vertical height of the boiler is, roughly, about 20 per cent. greater than its length. The space between the sides of adjacent boilers required for the use of cleaning tools is about 5 feet.

Tube and Plate Heating Surfaces. — General proportions as to these are shown by the following data, which refer to the *Illinois* (eight single-ended Scotch boilers), of the *Alabama* class, and to the gunboat *Dubuque* (two Babcock and Wilcox boilers).

Illinois

Heating surface, one boiler:	
Tubes, square feet	2,273.7
Furnaces (four), square feet	176.4
Combustion chambers (two), square feet	256.0
Total	2,706.1
Tube heating surface, per cent.	84

Dubuque

Heating surface, one boiler:	
Tubes, square feet	1,970.7
Side boxes and drum, square feet	108.8
Total	2,079.5
Tube heating surface, per cent.	95

I. H. P. per Square Foot of Grate and Heating Surface. — The following data refer to the contract trials of the *Wisconsin* (cylindrical), of the *Alabama* class, the protected cruiser *Charleston* (Babcock and Wilcox), previously noted, and the protected cruiser *Galveston* (six Babcock and Wilcox boilers; I. H. P., 5,178.5, all machinery).

	Wisconsin.	*Charleston.*	*Galveston.*
Air pressure in fire room, inches of water	0.924	2.48	2.00
Coal per hour per square foot G. S., pounds	37.2	40.9	33.41
Coal per hour per square foot H. S., pounds	1.123	0.895	0.758
I. H. P. (total) per square foot G. S.	19.7	19.65	17.26
I. H. P. (total) per square foot H. S.	0.5946	0.4298	0.3923

Ratio of Heating to Grate Surface. — In the three vessels, as above:

	H. S. ÷ G. S.
Wisconsin	33.13
Charleston	45.71
Galveston	44.00

In the cylindrical boiler the length of the grate is limited by the relatively small diameter of the furnace and by the draught. This restriction does not apply to the water-tube boiler. In the three vessels, as above, the lengths of the grate are, respectively, 6 feet $1\frac{7}{8}$ inches, 7 feet, and 6 feet 6 inches. The percentage of air space in naval grates is usually 43.

Furnace Volume; Combustion Gas Passages. — In the *Illinois* (cylindrical), of the *Alabama* class, the ratio of the volume of the furnaces and combustion chambers above the grates to the grate surface is 4.07. The average height of the Babcock and Wilcox furnace is about 2 feet 9 inches, making this ratio for the furnace alone 2.75. With moderate forced draught, the flame from the furnace generally reaches as far as the middle of the second "pass." On the trial of the *Denver* (*Galveston* class), with 0.9-inch air pressure, the flame went into the third pass.

In the *Illinois* (cylindrical) the ratio of the area through the tubes to the grate surface is 0.16. The *Dubuque* (Babcock and Wilcox), previously noted, on her contract trial burned 19.08 pounds of coal per square foot of grate surface with an air pressure in fire rooms of 0.125 inches of water. The ratio of heating to grate surface is 41.68. The grate surface is 49.9 square feet. The area for the passage of the gases of combustion is, in

First section	10.36 square feet
Second section	10.2 square feet
Third section	8.6 square feet
Uptake section	8.2 square feet

giving ratios of these areas to grate surface of 0.208, 0.204, 0.172, and 0.164, respectively.

The height of the smoke pipes (two) above the grate is in this

case 60.33 feet. Each is 37 inches in diameter, with a sectional area of 7.4666 square feet, giving a ratio of smoke pipe area to grate surface of 0.149.

Steam Space and Steam Liberating Surface. — Too small a steam space causes priming, the water being carried off as spray with the steam; too large a space increases the radiation losses. In comparing the cylindrical and the Babcock and Wilcox boilers in this respect, and under similar conditions otherwise, the relative volumes per pound of the steam at the working pressures should be considered. The following data relate to the *Illinois* (cylindrical) and the *Galveston* (Babcock and Wilcox), both referred to previously.

	Illinois.	*Galveston.*
Steam pressure, pounds, gauge	177.0	264.0
I. H. P. per boiler	1,612.0	863.0
Heating surface, one boiler, square feet	2,706.1	2,200.0
Grate surface, one boiler, square feet	85.6	60.0
Steam space, one boiler, with water 4 inches above highest heating surface, cubic feet,	355.0	. .
Steam space above plane of centres of circulating tubes and drum, cubic feet	. .	50.44
Steam space per I. H. P., cubic feet	0.22	0.058
Steam space per square foot heating surface, cubic feet	0.13	0.023
Steam space per square foot grate surface, cubic feet	4.14	1.01

The steam space per I. H. P. of the Babcock and Wilcox boiler is thus about one-fourth that of the cylindrical boiler cited, with, in this respect, a marked reduction in the losses by radiation.

At the water levels given above:

	Illinois.	*Galveston.*
Steam liberating surface, square feet	116	72.14
Liberating surface per I. H. P., square feet	0.072	0.084
Liberating surface per square foot heating surface, square feet	0.043	0.033
Liberating surface per square foot grate surface, square feet	1.355	1.44

It will be seen that the steam liberating surface is ample. With regard to this matter the Babcock and Wilcox Company report[1] the following experiment (Figure 8):

[1] Marine Steam, Babcock & Wilcox Company, p. 100.

"A peephole, filled with a stout piece of glass, was made in each drumhead opposite the space between the return circulating tubes and the baffle plate. By means of an electric arc light placed at one eye-piece the interior of the drum was illuminated and the discharge of each of the circulating tubes distinctly seen.

"When the boiler was steaming rapidly, with ¾-inch air blast in the ash pit, the observations clearly showed that each of the circulating tubes was discharging against the baffle plate with considerable velocity a stream of solid water that filled the tube for half its diameter.

"There was no spray of mist whatever, showing conclusively that the steam had entirely separated from the water during its passage

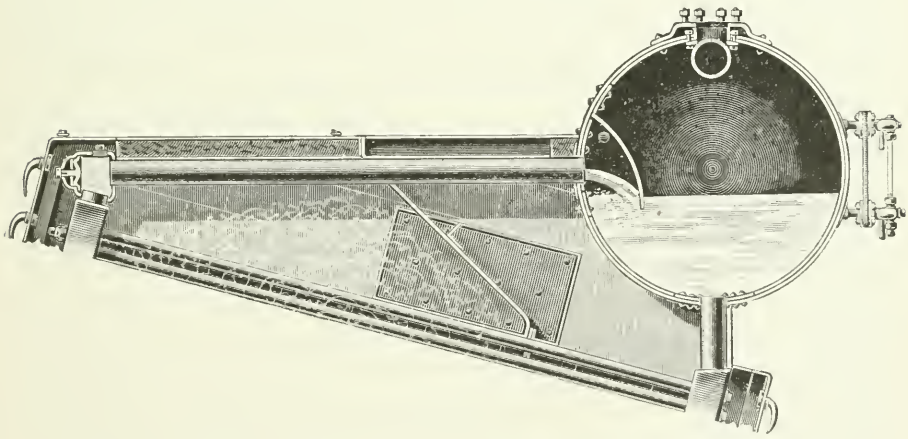


Fig. 8. — Partial Vertical Section, Showing Steam-Liberating Action

through the circulating tubes, which in this boiler were only 50 inches long by 4 inches in diameter. As a matter of fact, the actual steam-liberating surface required for the entire boiler was less than that contained in the circulating tubes, which amounted to about 15 square feet, or 1 square foot to every 100 square feet of heating surface in the boiler."

Quality of Steam. — This boiler, under the conditions of a shore test, furnishes steam which may be considered as perfectly dry. This is true also in a smooth sea when there is neither oil nor salt in the feed. In tests made by boards of United States naval officers the average amount of moisture found in the steam was: in the *Alert* boiler, seven-tenths of one per cent.; *Cincinnati* boiler, six-tenths of one per cent.; *Nebraska* boiler, five-tenths of one per cent.

One reason for this is that the steam-liberating surface is relatively large, being .084 square foot per I. H. P. in the *Galveston*, whose steam pressure on trial was 264 pounds gauge, as compared with .072 square foot on the *Illinois*, with a corresponding pressure of 177 pounds. Again, the normal water level is in the plane of the centres of the circulating tubes, as shown in Figure 8. Hence time is an important factor, since from the instant of entrance into the circulating tubes and during passage through them steam may free itself. Finally, the drum is not exposed to great heat, and therefore the water is not agitated in any way except by the rolling and pitching of the vessel. The "swash plates" fitted in the drum act to minimize the effect of the motion of the hull.

Water Endurance. — The time taken to evaporate the water from the normal water level to the "danger line," *i. e.*, the level of the highest heating surface, is important, since the feed may at times fail through accident or neglect. While accurate data on this point are not at present available to the lecturer, the following approximations are close enough to serve.

In the boilers of the *Illinois* (cylindrical) previously noted the gross volume, including combustion chamber staying, between the two levels, as above, is about 38.3 cubic feet. In the boilers of the *Nebraska* (Babcock and Wilcox) the first gauge cock is located above but close to the level of the highest point of the generating tubes. This level — assuming that the circulating tubes and drum are never exposed to great heat — may be taken as corresponding with the tops of the combustion chambers in the cylindrical boiler, although the two cases are not wholly the same in the exclusion of this heating surface and in the usual location of the lowest gauge cock in the cylindrical type.

In the test of the *Nebraska's* boiler it was found that to raise the water level from the first gauge cock to the centre of the drum required 2,619 pounds of water at 62° F. This corresponds with a volume of 42 cubic feet.

Taking the horse power of the main engines only :

	Illinois.	*Nebraska.*
I. H. P., main engines	12,647	19,000
Number of boilers	8	12
I. H. P. per boiler	1,581	1,583
Water space from normal level to "danger line," cubic feet	38.3	42
Water space from normal level to "danger line," per boiler H. P., cubic feet	0.0242	0.0265

The working pressure of the cylindrical boiler is 175 pounds gauge and that of the Babcock and Wilcox boiler 275 pounds gauge, with — taking Dr. Thurston's figures — weights of water per cubic foot of 54.5 and 53.1 pounds, respectively. Hence the water-tube boiler at working pressure will contain a less weight of water per cubic foot of space. On the other hand, the main engines at the higher working pressure should use a smaller weight of steam per I. H. P. In any event, it is clear that, with the assumptions as above, the Babcock and Wilcox boiler closely approaches in water endurance the marine cylindrical boiler cited.

Speed of Circulation. — The factors combining to produce circulation in this boiler have been noted. Mr. George H. Babcock, in a lecture at Cornell University in February, 1890, gave the following interesting discussion of the approximate speed of circulation in land boilers of this type:

"In such a construction the circulation is a function of the difference in density of the two columns. Its velocity is measured by the well-known Torricellian formula, $V^2 = 2gh$, or, approximately, $V = 8\sqrt{h}$, h being measured in terms of the lighter fluid. This velocity will increase until the rising column becomes all steam, but the quantity of weight circulated will attain a maximum when the density of the mingled steam and water in the rising column becomes one-half that of the solid water in the descending column, which is nearly coincident with the condition of half steam and half water, the weight of the steam being very slight compared to that of the water.

"Let us take, for example, one of the 240-horse-power Babcock and Wilcox boilers here in the university. The height of the columns may be taken as $4\frac{1}{2}$ feet, measuring from the surface of the water to about the centre of the bundle of tubes over the fire, and the head would be equal to this height at the maximum of circulation. We should, therefore, have a velocity of $8\sqrt{4.5} = 16.97$ — say, 17 feet per second.

"There are in this boiler fourteen sections, each having a 4-inch tube opening into the drum, the area of which (inside) is 11 square inches, the fourteen aggregating 154 square inches, or 1.07 square feet. This multiplied by the velocity, 16.97 feet, gives 18.16 cubic feet of mingled steam and water discharged per second, one-half of which, or 9.08 cubic feet, is steam. Assuming this steam to be at 100 pounds gauge pressure, it will weigh 0.258 pound per cubic foot. Hence 2.34

pounds of steam will be discharged per second and 8,433 pounds per hour. Dividing this by thirty, the number of pounds representing a boiler horse power, we get 281.1 horse power — about 17 per cent. in excess of the rated power of the boiler.

"The water at the temperature of steam at 100 pounds pressure weighs 56 pounds per cubic foot, and the steam 0.258 pound, so that the steam forms but $\frac{1}{218}$ part of the mixture by weight; and consequently each particle of water will make 218 circuits before being evaporated when working at this capacity and circulating the maximum weight of water through the tubes.

. . . "In designing boilers of this style, it is necessary to guard against having the uptake at the upper end of the tubes (the rear header in the marine Babcock and Wilcox) too large, for if sufficiently large to allow downward currents therein the whole effect of the rising column in increasing the circulation in the tubes is nullified. This will readily be seen if we consider the uptake very large, when the only head-producing circulation in the tubes will be that due to the inclination of each tube taken by itself. The objection is only overcome when the uptake is so small as to be entirely filled with the ascending current of mingled steam and water. It is also necessary that this uptake should be practically direct, and it should not be composed of frequent enlargements and contractions." [1]

The theoretical circulation, as calculated above, is, of course, affected by bends and the friction of tubes and passages. In the later forms of the marine Babcock and Wilcox boiler the length of the 2-inch tubes is 48 diameters. In the bottom row, however, where the circulation is most vigorous, the diameter is 4 inches, giving a tube length of 24 diameters, which is the theoretically correct length, according to the London *Engineer*.

Baffling. — Assuming fair water circulation — which in most cases may readily be obtained — an effective system of baffling the gases is vital to the efficiency of the water-tube boiler at high rates of combustion, since it prolongs the duration of contact of the gases and heating surfaces, and hence increases the interval for heat absorption by the water. Such a system is frequently difficult to design and apply. Many water-tube boilers, in fact, fail markedly in this respect.

In the Babcock and Wilcox marine boiler the gas currents, in the

[1] Steam, Babcock & Wilcox Company, 1902, p. 21.

first place, meet the tubes at right angles; secondly, the tubes are staggered vertically. Owing to these two conditions the gas currents are broken and their flow impeded. Mr. Watt, whose experiments have been referred to previously, found that tubes placed in vertical rows gave a maximum evaporation which was but 82 per cent. of that shown by tubes staggered as above.

Again, the space between the tubes is divided into three sections, or "passes," as has been shown, by two baffles set perpendicularly to the tube axes, so that the gases are forced to cross the tubes three times on their way from the furnace to the uptake. This circuitous route gives them a travel of about 16 feet before exit, which distance, it is stated, is longer than the similar travel in any marine water-tube boiler, and is, in any event, sufficient to obtain fair and sustained efficiency at the higher rates of combustion.

Gas Temperatures. — In June, 1900, tests were made by a naval board upon a Babcock and Wilcox boiler built for the United States cruiser *Cincinnati*. The grate surface was 63.25 square feet, the heating surface 2,640 square feet, and the boiler was fitted with an air heater located at the base of the uptake. In the tests noted below the air heater was not used. The temperatures of the gases were found at various locations by the melting points of different metals. The system of baffling was that which has just been described. The "fractions of travel" represent portions of the total travel of the gases from the beginning to the end of the tubes in crossing the latter three times. The tests were:

1. Full grate; coal per square foot grate per hour, 35.08 pounds; water per square foot heating surface from and at 212°, 8.78 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{9}{12}$	1,160°
$\frac{11}{12}$	842°
$\frac{2}{12}$	780°
$\frac{1}{12}$	625°
Flue temperature	601°

2. Length of grate shortened, making grate surface 52 square feet; coal per square foot grate surface per hour, 50.38 pounds; water per square foot heating surface from and at 212°, 10.07 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{7}{12}$	1,160°
$\frac{11}{12}$	852°
$\frac{26}{12}$	780°
$\frac{41}{12}$	650°
Flue temperature	640°

3. Full grate, coal per square foot grate surface per hour, 59.2 pounds; water per square foot heating surface from and at 212°, 13.68 pounds.

Fraction of Travel	Gas Temperature, F.
$\frac{18}{12}$	1,160°
$\frac{35}{12}$	870°
Flue temperature	850°

In test No. 1, which is nearest to the normal steaming of this boiler, there is a very marked fall of temperature in passing upward from 64 per cent. to 80 per cent. of the height of the first pass; from the latter point to the end of the tube surface the fall is gradual, almost rectilineal when plotted. The furnace temperature and that of the tubes to the first point noted were not observed.

Sir A. J. Durston[1] discusses in this respect a test of a return five-tubular marine boiler, worked at its normal capacity, the consumption of coal being 17 pounds per square foot grate surface. The temperature in the combustion chamber was 1,644° F.; just inside the tube, 1,550°; in tube, 1 inch from combustion chamber, 1,466°; 2 inches, 1,426°; at end of tube, 887°; in smoke box, 782°. About $\frac{2}{11}$ of the total fall of temperature took place in the first 2 inches of the tube, after which the fall was fairly evenly distributed throughout its length.

Steam Raising. — In the *Cincinnati* tests fires were started on a cold boiler, lightwood being used and the blower running (closed stokehold system). Steam formed in five minutes, and in twelve minutes forty seconds had reached a pressure of 215 pounds gauge. To raise steam in the cylindrical boiler, without special appliances for circulation and without endangering its complex structure, requires from five to ten hours, depending mainly upon whether the boiler is single or double ended.

Rapidity in raising steam, which is a characteristic of the water-tube

[1] Transactions of the Institute of Naval Architects, March 23, 1893.

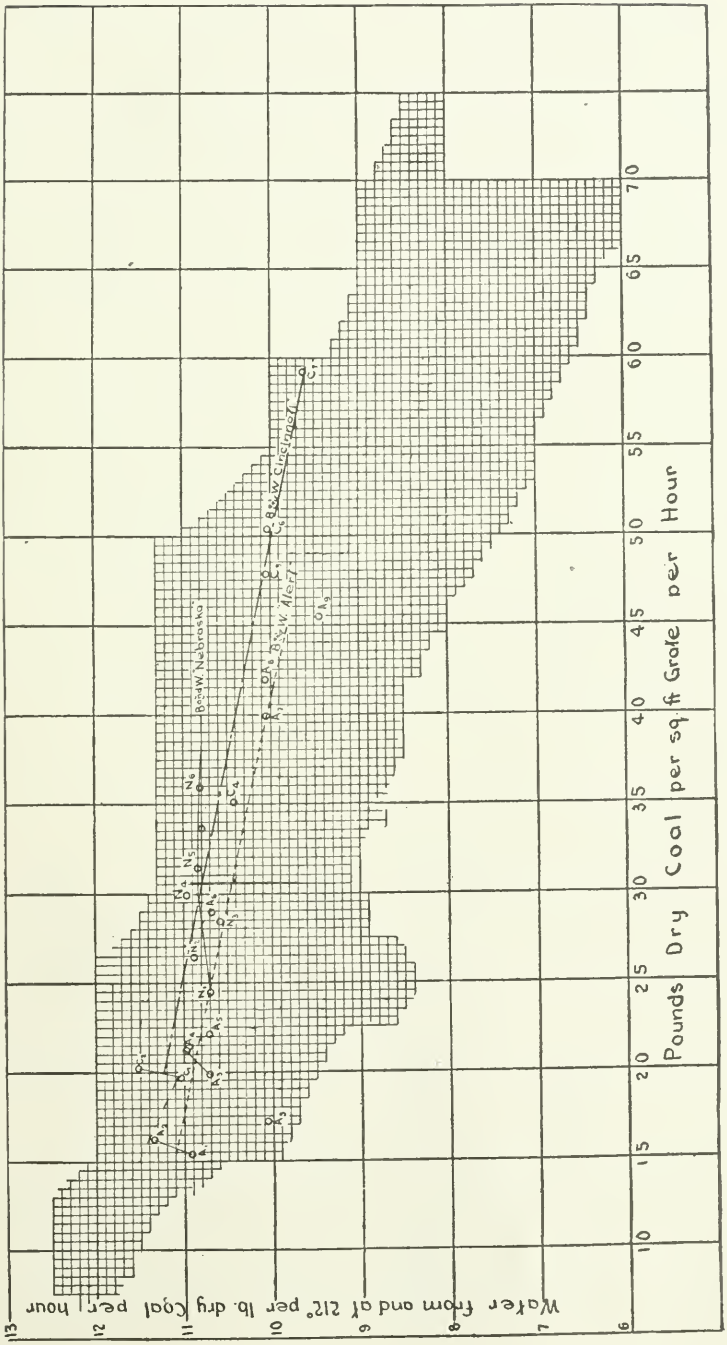


FIG. 9.— EVAPORATIVE EFFICIENCY

boiler in general, is, in navies, of the greatest tactical value. It is a well-known fact that owing to the inherent defect in this respect of the cylindrical boiler our fleet was, as a whole, unprepared for steaming at full speed when Cervera's squadron made its dash from Santiago. If the ships had been fitted with water-tube boilers the difficult problem which confronted the fleet in maintaining its preparedness for immediate action at full speed would have been solved. As it was, banked fires under the full installation required a heavy expenditure of fuel; coaling at sea off Santiago was often impossible, and the retirement of a ship to Santiago for that purpose meant her absence from a possible battle line.

Rapidity in raising steam is sometimes a factor of much importance in the merchant service also. If, as on the Great Lakes, the unloading facilities are such that the stay of large freight steamers in port may be limited to about six hours, only the water-tube boiler will prevent unnecessary detention, since in that restricted period the cylindrical boiler would scarcely have time to cool, leaving its cleaning, repairs, and slow steam raising yet to be done.

Evaporative Efficiency. — Three exhaustive tests of Babcock and Wilcox marine boilers, built for the United States Navy, have been made by naval boards. These tests are:

1. *Alert's* boiler, April, 1899. Heating surface, 2,125 square feet; grate surface, 48 square feet.

2. *Cincinnati's* boiler, June, 1900. Heating surface, 2,640 square feet; grate surface, 63.25 square feet.

3. *Nebraska's* boiler, December, 1903. Heating surface, 4,682 square feet; grate surface, 111.72 square feet.

For complete data of these tests see *Journal of American Society of Naval Engineers*, Volume XI, No. 2; Volume XII, No. 4; Volume XVI, No. 1. The evaporative results, as plotted by Lieutenant Commander Bryan, are given in Figure 9, the abscissæ being pounds dry coal per square foot grate surface per hour, and the ordinates the pounds water evaporated from and at 212° per pound dry coal per hour, both as given in the table on page 153.

These three tests of the Babcock and Wilcox marine boiler represent successive designs showing the success of the efforts to increase its efficiency by baffling, the general form of the latter being, however, the same in all and that which has been described previously. The results are not strictly comparative, since in both the *Alert* and

Type of boiler.		Duration of test, hours.	Draft in ash pits, inches of water.	Coal per sq. ft. of grate, pounds.	Water from and at 212° per pound dry coal.	Temperature gases in base smoke pipe.	Steam pressure per gauge, pounds.	No. of point on curve.	Remarks.
					Pounds	F.°			
Babcock and Wilcox, *Nebraska* Test made on shore	G. S. = 111.72 sq. ft. H. S. = 4,682 sq. ft.								
	Weight, dry	7	. . .	24.48	10.70	673.0	. . .	N_1	Closed ash pit
	Weight, dry	8	. . .	26.46	10.89	659.0	. . .	N_2	Closed ash pit
	water	8	. . .	28.56	10.57	680.0	. . .	N_3	Closed fire room
		7½	. . .	29.99	10.97	688.0	. . .	N_4	Closed fire room
	wet	8	. . .	31.46	10.83	716.0	. . .	N_5	Closed ash pit
		5	. . .	36.09	10.80	693.0	. . .	N_6	Closed fire room
Babcock and Wilcox, *Cincinnati* Tests made on shore	G. S. = 6,325 sq. ft. H. S. = 2,640 sq. ft.								
	*Reduced grate = 52 sq. ft.	8	.25	19.61	11.03	466.0	209.3	C_1	Draught heated to 458°
	Weight, dry	8	.107	20.19	11.51	493.0	206.6	C_2	Draught heated to 509°
		6	1.42	33.51	10.49	608.6	210.6	C_3	
	water	6	1.37	35.08	10.41	570.6	207.4	C_4	
		4	1.45	47.81	10.17	637.0	209.8	C_5	Reduced grate.* Draught heated to 674°
	wet	4	1.37	50.38	10.14	640.0	213.6	C_6	Reduced grate.*
		3½	1.685	59.23	9.63	900.0	210.8	C_7	
Babcock and Wilcox, *Alert* Test on shore	G. S. = 48 sq. ft. H. S. = 2,125 sq. ft.								
	Weight, dry	. .	.23	15.35	10.93	. . .	. . .	A_1	. . .
		. .	.26	16.16	11.33	. . .	. . .	A_2	. . .
	water	. .	.43	19.85	10.72	. . .	. . .	A_3	. . .
		. .	.61	21.14	10.97	. . .	. . .	A_4	. . .
	wet	. .	.55	22.06	10.70	. . .	. . .	A_5	. . .
		6	1.14	28.82	10.66	521.0	218.0	A_6	Anthracite coal
		6	1.82	39.93	10.05	581.0	. . .	A_7	Draught heated. Jet and blower draught
	wet	6	1.91	41.88	10.06	567.0	220.0	A_8	Draught heated
		6	1.93	45.39	9.41	619.0	219.0	A_9	Draught heated
	46,110 pounds								
	7,660 pounds								
	53,770 pounds								

Cincinnati tests heated draught and different coals were used in some cases. The *Nebraska's* boiler was baffled to obtain certain results, it being calculated to burn a little over 30 pounds per square foot grate surface at a fire-room pressure of 1 inch of water.

Differences in other respects are, however, overshadowed by the one source of error which cannot be eliminated, viz., the quality of the firing. In view of this consideration the test results may be compared without material error. The *Nebraska's* boiler showed a sustained evaporative efficiency through a fairly wide range of coal consumption. In burning from 25.52 to 37.88 pounds dry coal per square foot grate surface per hour, the evaporation ranged between 10.57 and 10.97 pounds water from and at 212° per pound coal. Both the *Cincinnati* and *Alert* tests show a steady but moderate and uniform fall in evaporation, with increased coal consumption. The influence of a good system of baffling is marked in these results.

With regard to the evaporation per hour per square foot of heating and grate surface, the latest tests — those of the *Nebraska* — give:

Dry coal per square foot grate surface, pounds	25.52	31.50	37.88
Dry coal per square foot heating surface, pounds	0.609	0.752	0.904
Water from and at 212° per square foot grate surface, pounds	273.2	346.1	409.2
Water from and at 212° per square foot heating surface, pounds	6.52	8.26	9.77

Boiler Efficiency. — On the basis of the consumption of dry coal per hour per square foot grate surface, the efficiencies of the boilers were in the

	Coal.	Efficiency.
Alert	19.85	70.65
Alert	28.82	74.60
Alert	41.88	67.30
Alert	45.39	61.95
Cincinnati	19.61	73.1
Cincinnati	20.19	74.3
Cincinnati	33.51	70.6
Cincinnati	35.08	70.1
Cincinnati	50.38	67.5
Cincinnati	47.81	69.0
Cincinnati	59.23	63.4

The report of June, 1904, of the British Committee on Naval Boilers states:

"The best results obtained with the Babcock and Wilcox boilers of the *Hermes* were during the trials of the furnace-gas baffling, the boilers in the middle boiler room, with vertical baffles and a forced air supply over the fires, giving the high efficiency of 81 per cent. on a thirty hours' trial when 20 pounds of coal were burned per square foot of fire grate per hour, and an efficiency of 77.8 per cent. on a twenty-nine hours' trial when burning 27 pounds per square foot, these rates of combustion corresponding to the ordinary rate of steaming and to the full power of the boilers, respectively."

Efficiency of Combustion. — In the tests of the *Nebraska's* boiler, No. 1 was made with closed ash pit, $\frac{1}{2}$ inch draught; No. 5 with closed fire room and 1 inch draught; No. 6 with closed fire room and $1\frac{1}{2}$ inches draught. Other data of these three tests are:

	Test No.		
	1	5	6
Dry coal per hour per square foot grate surface, pounds	25.52	31.5	37.88
Flue gases CO_2	12.7	13.25	9.95
Flue gases O	5.27	6.15	9.40
Flue gases CO	0.8	0.0	0.0

Coal per I. H. P. — The "pounds coal per I. H. P." is a time-honored although scarcely accurate measure of boiler performance in marine trials. It assumes, in such comparisons, the same quality of coal and skill in firing, the same losses in the steam pipes, and the same weight of steam of the same heat value as expended per I. H. P. through installations which may vary somewhat widely in their character. The following data relate to three of the last battleships with cylindrical boilers built for the United States Navy, and to the latest published trials of ships with Babcock and Wilcox boilers constructed for that service.

	Boilers.	Coal, Pounds	I. H. P.
		Per I. H. P., all machinery.	Per square foot grate surface.
Battleship *Kearsarge*	Cylindrical	2.36	17.45
Battleship *Kentucky*	"	2.63	18.00
Battleship *Wisconsin*	"	1.88 (Welsh coal)	19.70
Battleship *Louisiana*	Babcock and Wilcox	1.973	19.46
Armored cruiser *West Virginia* . .	" " "	3.037	16.54
Armored cruiser *Maryland*	" " "	2.849	17.79
Protected cruiser *Charleston* . . .	" " "	2.08	19.65
Protected cruiser *Chattanooga* . .	" " "	1.97	17.99
Protected cruiser *Galveston*	" " "	1.935	17.26
Protected cruiser *Denver*	" " "	2.36	20.675
Protected cruiser *Tacoma*	" " "	2.16	18.08
Protected cruiser *Cleveland*	" " "	1.995	15.616
Gunboat *Paducah*	" " "	2.129	12.705
Gunboat *Dubuque*	" " "	1.559	12.228

The three ships with cylindrical boilers average 2.29 pounds coal per I. H. P.; the eleven with Babcock and Wilcox boilers average 2.186 pounds.

When, as in relatively few cases, a single installation is composed of both cylindrical and water-tube boilers practically all uncertainties in this comparison are removed. *Engineering*, London, April 28, 1905, Volume LXXIX, page 550, says:

"One of the King Edward VII battleships, which has the combination system, was ordered to run four trials of eight hours' duration in order to test the comparative evaporation of the same proportion of cylindrical and Babcock and Wilcox boilers. The first trial was with Babcock and Wilcox boilers, equal to one-fifth total power, and the second with cylindrical boilers, also equal to one-fifth of the total power. It was found that whereas the former gave 3759 I. H. P., the tank boilers gave only 3634 I. H. P.; the coal consumption was 1.74 lb. and 1.8 lb. per I. H. P. per hour, respectively. The third trial was with all the cylindrical boilers working under full-power trial conditions, under an air pressure not exceeding 1 in.; while the fourth trial was with an equal proportion of boilers of the Babcock and Wilcox type, burning an equal amount of coal to that used by the cylindrical boilers in the third trial, and run so as to attain as high a power as possible.

The cylindrical boilers were supposed, when the design was prepared, to be equal to two-fifths of the full power — namely, 7200 I. H. P.; but on this special trial, when worked at an air pressure of 0.96 in., it was found that the total power got was only 6686 I. H. P., showing that they were deficient to the extent of nearly 10 per cent. The total coal burned on the eight hours' trial was 100,890 lb., equal to 1.88 lb. per I. H. P. hour. An equal proportion of Babcock and Wilcox boilers, working at the same power, and burning in the eight hours 100,498 lb. of coal, the air pressure in the stokehold being 0.8, gave 7510 I. H. P., which was 300 more than was anticipated, while their coal consumption was only 1.67 lb. per I. H. P. per hour. In other words, for the same coal consumption, the water-tube boilers gave over 12 per cent. more power, and the ratio of consumption to power was 0.21 lb. less per unit of power per hour = 11 per cent. less than with tank boilers."

Forced Draught. — For full efficiency under forced draught a boiler should have sufficient furnace volume for complete combustion at the maximum rate of coal comsumption to be attained; an area of heating surface adequate, when fully effective, to lower the temperature of the maximum weight of combustion gases thus produced to that of the normal temperature of the stack; and a system of baffling — either by tube walls or sheet-metal partitions — so designed as to make the whole area of the heating surface effective and to give the greatest possible travel to the gases in their passage from furnace to uptake, while not increasing unduly the draught resistance of the boiler.

These are the ideal conditions for fully efficient forcing — conditions which the limitations of marine practice make difficult of fulfillment. It is true that large powers have been developed at low air pressures by the high forcing of boilers whose absence of baffling gave them slight draught resistance; but the expenditure of fuel per boiler horse power is in such cases correspondingly large, since the gases take the shortest road to the uptake, the entire heating surface is not effective, and the stack temperature is abnormally high.

In the *Cincinnati* tests the Babcock and Wilcox boilers reached a maximum consumption of 59.23 pounds dry coal per hour per square foot grate surface, the temperature of the escaping gases from the boiler being given as "less than 900° F.," the equivalent evaporation — from and at 212° — as 9.63 pounds, and the boiler efficiency, on the dry

coal basis, as 63.4 per cent. In the *Nebraska* tests, at a consumption of 37.88 pounds dry coal per hour per square foot grate surface, the equivalent evaporation from and at 212° was 10.8 pounds per pound of dry coal, which amount was 98.4 per cent. of the maximum evaporation, the latter having been obtained at a coal consumption of 31.5 pounds.

Lieutenant Commander Bryan states, as to naval practice: "It is not believed that more than 40 pounds coal per square foot grate surface per hour can be maintained for ninety-six hours, nor more than 45 to 50 pounds for twelve hours under service conditions" — an opinion which is fully sustained by knowledge of the added and severe work of the fire room complement, especially with the closed stokehold system, and of the rapid clogging of the grate bars under any system. In the *Nebraska* tests the Babcock and Wilcox boiler seems to have come fairly close to the 40-pound limit, and with fair evaporative efficiency.

The *Nebraska's* boiler had two furnaces, each with three fire doors, and both opening into the same tube space above. A fact which was brought out on these tests was that the closed ash-pit system of forced draught was unsuitable for high rates of combustion in a boiler of this type. "It was found, with even the lowest draught pressure used, that it was not safe to work the fires when under ash-pit draught without closing off the draught from both furnaces," since the firemen were endangered by a cloud of sparks from the fires. As a result the draught was entirely closed off on Test I for 23.4 per cent., on Test II for 24.6 per cent., and on Test III for 28.4 per cent. of the whole time of the test.

Make-up Feed. — A minor objection which has been urged against boilers having joints in the water space, similar to the hand-hole plates at the tube ends of the Babcock and Wilcox boiler, is the additional amount of "make-up feed" required, owing to the loss from leakage at such joints. The total loss covers, of course, all leakage at the engine and auxiliaries, the escape at the safety valves, etc.

An old and apparently low estimate for the loss with cylindrical boilers is 1 ton of make-up feed per 1,000 I. H. P. of main engines for each twenty-four hours. Commander White[1] found for the United States cruiser *Minneapolis* (cylindrical boilers) a feed loss of 6.58 tons per 1,000 I. H. P.; when the engines were running at 8 per cent. of their maximum power, Lieutenant Dinger[2] estimates the make-up feed

[1] Journal of the American Society of Naval Engineers, X, No. 1.

[2] *Ibid.*, XV, No. 1.

of the United States steamship *Marietta* (Babcock and Wilcox boilers) as 4 to 5 tons per 1,000 I. H. P. per day. The British Committee on Naval Boilers, in the report previously cited, give the feed loss of the *Hermes* (Babcock and Wilcox boilers) as 3.8 tons per 1,000 H. P. per day, which the committee state is "moderate."

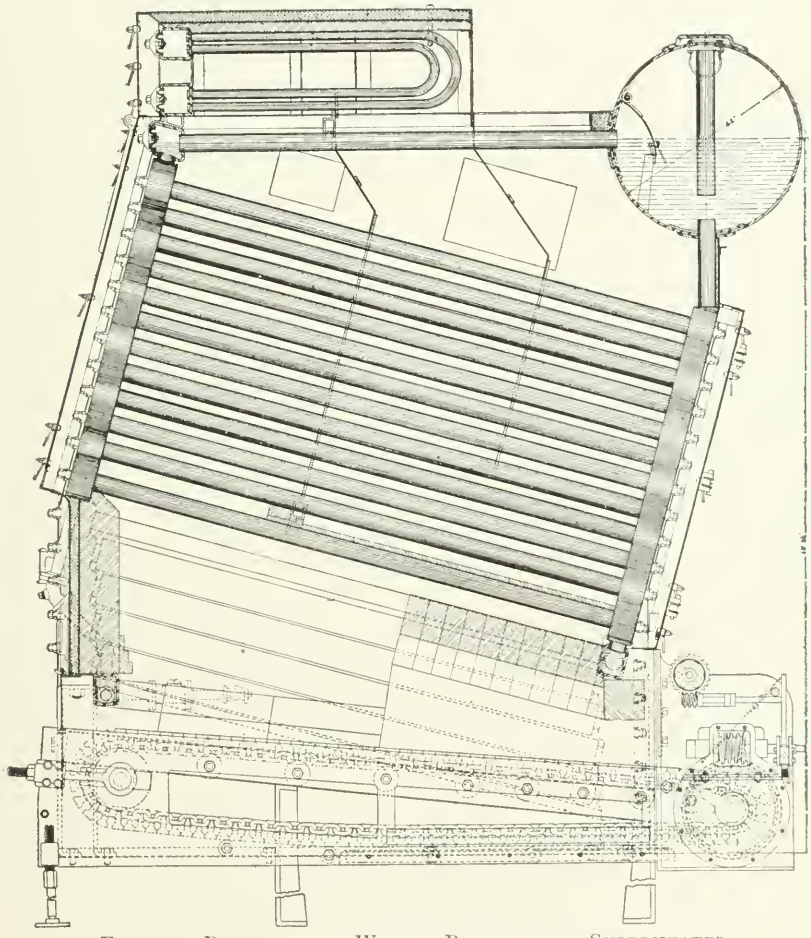


FIG. 10.— BABCOCK AND WILCOX BOILER WITH SUPERHEATER

Against the increased loss of feed from the number of hand-hole plates in the Babcock and Wilcox boiler there must be balanced the advantage which these plates give of ready access to the water side of the heating surface. This advantage is one factor in maintaining the efficiency of this boiler in continuous service.

Firing. — A further objection frequently advanced against the water-

tube boiler is that a higher degree of skill in firing is required to secure good results than with the cylindrical boiler. This is quite true, owing to the smaller amount of contained water and to the larger area of grate surface in a single furnace. There should be a uniform thickness of fire, since an inrush of cold air will occur at thin spots. As a general rule, firing thinly, evenly, and often is essential for efficiency.

In the *Nebraska* tests the total grate surface was 111.72 square feet; number of furnaces, two; doors per furnace, three; grate surface per door, 18.62 square feet. In burning 37.88 pounds dry coal per hour per square foot grate surface, the average amount of coal fed at each door at each coaling was 101.8 pounds; the average time between consecutive coalings or levelings at the same door was eight minutes twenty-one seconds; and the average coal fired at each coaling (three doors) was 305.4 pounds.

Feed Appliances. — There are no special feed appliances in the Babcock and Wilcox boiler. The system, in valves, piping, and pumps, is practically the same as with the cylindrical boiler.

Cleaning and Repairs. — The tubes are staggered vertically only and not horizontally. Hence they lie in horizontal rows, leaving "lanes" between the rows for the insertion of the steam lance in blowing soot from the tubes. This method removes the bulk of the soot, which is carried up the smoke pipe by the draught. When the boiler is out of use the cleaning or "dusting" doors give access to each "pass."

The straight tubes and expanded joints of this boiler make repairs to the pressure parts simple. Of those parts the headers are the only ones of special form. These in manufacture are subjected to a hydrostatic pressure of 600 pounds to the inch in order to detect leaks, defects in welding, etc.

Superheated Steam. — The Babcock and Wilcox Company has led in the reintroduction of the superheater in American vessels. Figure 10 shows this superheater as fitted in the boilers of the *James C. Wallace*, a lake steamer having one quadruple expansion engine of 2,000 I. H. P.

The superheater is located at the rear of the boiler above the circulating tubes, and consists of solid-drawn steel tubes bent in U-form, each connected by expanded joints to an upper and a lower cross box, or steam collector, of wrought steel. Steam is led from the steam and water drum to the upper box by an outside pipe, and, since there is one partition in each box, it flows three times through the tubes from one box to the other before leaving the

superheater for the engine by another outside pipe. Valves are fitted in the piping, so that the steam from the boiler may be sent either through the superheater or directly to the main steam line.

The principal data relating to the superheaters of the *Wallace* are:

Diameter of superheating tubes, inches	2
Thickness of superheating tubes, inches	10 B. W. G
Number of boilers	2
Grate surface, each boiler, square feet	74
Heating surface, each boiler, square feet	2,900
Superheating surface, each boiler, square feet	414
Ratio of grate surface to heating surface	1 to 39.19
Ratio of grate surface to heating surface, including superheating surface	1 to 44.78

As shown, a damper depends from the middle of the base of the superheater. In this position its lower edge rests upon the top of the rear upright baffle, and the gases are thus forced to flow around the superheater tubes on their way to the passage between the two upright baffles. In comparative tests[1] made by a board of officers of the United States Navy trials with superheated steam were made with this damper in position, and later with saturated steam, the damper being removed and the superheater blocked off by a fire-brick baffle laid on the circulating tubes.

The principal data of the tests are given below, Test I having been with superheated and Test IV with saturated steam. In these tests the conditions were closely similar, except as to the state of the steam and the points of cut-off, the latter differing in order to develop the same power with both superheated and saturated steam.

[1] Journal of American Society of Naval Engineers, XVII, No. 3.

	Test No.	
	I.	IV.
Duration, hours	8.0	6.0
Steam pressure, gauge, pounds:		
At boilers	237.6	238.7
At engine	233.7	237.8
Steam temperature, degrees F.:		
Leaving superheater	487.0	. .
At engine	482.2	. .
Superheat at engine, degrees F.	81.7	0.0
Vacuum, inches	24.5	24.6
Revolutions per minute	79.0	77.0
I. H. P., main engines only	1,559.2	1,530.5
Kind of draught	Natural	Natural
Draught (inches of water), base of smoke pipe	.22	.22
Temperature, base of smoke pipe, degrees F.	485.3	553.5
Pounds of coal:		
Per hour, as fired	2,362.5	2,700.0
Per I. H. P.-hour, dry	1.464	1.713
Per hour, per square foot grate surface, moist	15.96	18.24
Moisture, per cent.	3.38	2.88
Ashes in coal, per cent.	19.87	14.4

The power developed by the auxiliaries in use was not determined. The water evaporated was not weighed, as facilities were lacking. Tests as to quality, made during the trials with saturated steam, showed that the latter was practically dry.

A comparison based on dry coal per I. H. P.-hour shows a net saving in fuel by the use of superheated steam of 14.5 per cent. In considering this result, it should be noted that it represents the aggregate saving throughout the entire plant and not only that due to the main engines. The proportionate saving for the main engine can be determined only from data as to its steam consumption, which data are, as stated, lacking in this case.

BLACK SAND OF THE PACIFIC COAST

By ROBERT H. RICHARDS

(Read December 14, 1905)

Dr. Day, Chief of the Department of Mineral Resources of the United States, when looking for lines along which the United States Geological Survey could serve the people, was impressed with the possibilities of black sand, and in 1897 and 1898 visited many beaches on sea and rivers, panning the sands for gold and platinum. He concluded that the troublesome black sand was worth investigation. Congress early in 1905 appropriated $25,000 for this work.

The Lewis and Clark Exposition of 1905 gave the opportunity for the concentrating pavilion and the concentrating machines, together with a supply of power and water. The Board of Trade of Portland furnished sea sand and river sand in carload lots. The hydraulic plants and dredges furnished clean-up sand and tailings for the tests.

Dr. Day brought together an efficient corps of workers for the Pavilion and the Mines Building. The miners washing gold in any part of the United States were invited to send 4-pound samples by mail for tests. These were examined for interesting minerals by Dr. C. H. Warren, assisted by Mr. Loughlin, and were assayed for gold, platinum, iridium, and iridosmine by Mr. C. E. Locke, assisted by Messrs. Barnaby, Brown, Glidden, Hayden, Reed, Johnston, and Whiting. When any samples showed interesting values the owners were asked for an additional quantity. In this way lots of from 100 pounds to 15 tons were received for investigation and treatment at the Pavilion; altogether 1,000 of the little samples and 250, more or less, of the larger quantities were examined.

These sands may be classified into sea beach, river beach, hydraulic tailings and clean-ups, dredge tailings and clean-ups, and finally ore from veins in place.

The interesting minerals proved to be magnetite, chromite, ilmenite, garnet, monazite, and zircon.

The usual fire assay treating 30 grams, while very satisfactory for richer ores, failed when samples carrying one cent, five cents, or twenty-five cents gold per ton were to be accurately valued. A two-gallon bottle revolving endwise with a little sodium amalgam — 50 grams — could treat 1,000 or 2,000 grams at a charge, and proved extremely valuable. Screens proved very useful, and the sizes adopted had 8 mm., 2 mm., and ½ mm. holes. Hand jigs proved valuable on the size larger than 8 mm. and the size between 8 mm. and 2 mm. They separated the gold and heavy minerals very effectively from the sands. The classifier is an instrument which acts by means of a current of water, which rises in a vertical tube and allows grains that can settle against the current to go down and out, while those that cannot do so rise and go over. A number of such tubes, with rising currents graded from faster to slower, can make a series of products decreasing in settling power. A classifier with twenty-four tubes, treating coarse gold in hydraulic clean-up sand, caught all the gold in the first three tubes — a very good result. But the same classifier treating sea-beach sand with fine flakes of gold showed some of that metal even in the twenty-fourth tube, and was entirely unsatisfactory. This sand proved to have been already classified by the waves.

The Wilfley table showed wonderful power, not only for saving coarse gold and platinum in clean-up sand, but for the fine leaf gold of the sea sand; and it also saved with ease the heavy minerals in the sand. It acts by a jerking motion which throws forward the heavy minerals into a sort of procession, while the lighter waste is thrown out and away from them on one side.

The Wetherill magnet is a valuable machine, and lifts out magnetic grains from a procession of sands passing under it on a belt and deposits them in a box by themselves, while the non-magnetic grains are dumped into another box by the belt. It usually has six magnetic poles, beginning with the weakest and ending with the strongest. In the Portland work the electric currents for these poles were:

0.2 amperes to lift out magnetite;
0.8 amperes to lift out ilmenite and chromite;
1.75 amperes to lift out garnet;
1.90 amperes to lift out hypersthene;
3.50 amperes to lift out monazite and to leave zircon behind.

Magnetite is the richest of the iron ores and is worth one-fourth of

a cent a pound. Chromite is valuable for colors, yellows and greens, and for chrome steel, which is worth one and one-half cents per pound. Ilmenite is beginning to attract electricians and may have a value later. Garnet for polishing powder may sell for one and one-half cents a pound, according to quality. Hypersthene has no value. Monazite (thorium phosphate) is used in making Welsbach light mantles and is valued at ten cents a pound. Zircon (zirconium silicate) is used in the same way and has the same value.

The electric steel furnace is as novel as any instrument employed in this investigation by the United States Geological Survey, and is more striking and spectacular. The furnace used at Portland is of experimental size. It consists of a hollow cylinder standing on end, 12 inches in diameter and 36 inches high inside. It is lined with fire brick except at the bottom, which has carbon bricks for conducting electricity, and under it is a heavy iron plate for distributing the electricity to the carbon bricks. The current used is 1,000 amperes at 56 volts. There was boundless enthusiasm among the Portland people who had gathered to see it when, in an hour and a half after this furnace was started cold on concentrates from the sea beach, 200 pounds of white hot steel was tapped from it. This furnace has proved immune from the harm of titanium, the bugbear which has wrecked so many efforts to use iron ores containing that metal. It is still in the experimental stage as to the means of controlling the contents of the steel in silicon, carbon, manganese, sulphur, and phosphorus. This control, as well as the means for obtaining sound ingots free from bubbles, will have to come by experiment. At the time of writing it does not look as if any of these would give serious trouble.

The cost of the furnace work on the little experimental furnace is estimated as follows:

4 men at $3 a day	$12.00
Electricity at 75 H. P., $50 per H. P. per year	12.00
1 anode 4 inches x 4 inches x 4 feet	6.00
Repairs	5.00
2,400 pounds steel cost	$35.00
1 ton (2,000 pounds) steel cost	29.00

Milling and furnace work on a basis of 100 tons per twenty-four hours:

Water concentration, 100 tons { lifting, 9c. per ton; washing, 6c. per ton }	15c.,	$15.00
Drying 49.8 tons at 20c.		10.00
Magnetic concentration, 49.8 tons at $1		49.80
Smelting into 16.1 tons steel at $29		467.00
		$541.80

Yield of 100 tons, best lot Fort Stevens[1]:

Magnetite, 32.2 tons, or steel, 16.1 tons, at 4c. a pound	$1,288.00
Ilmenite, 8.6 tons at a pound	
Garnet, 8.7 tons at 1½c. a pound	261.00
Monazite, 80 pounds at 10c. a pound	8.00
Zircon, 500 pounds at 10c. a pound	50.00
Gold and platinum, at 53c. a ton	53.00
	$1,660.00

NOTE. — Since the work is at present in a purely experimental stage the above figures are the best that the writer is able to give at this time. They will undoubtedly have to be modified, perhaps in some important directions; for example, the price of steel at four cents a pound may prove to be too high for the quality of steel that this furnace is able to produce.

[1] The sand selected for the following computation of yield and cost was the richest sand that came from the sea beach during the season. It came in a 15-ton lot from near Fort Stevens, near the mouth of the Columbia River. There is said to be a large quantity of it at that point.

The wisdom of selecting the richest sample may be questioned, as one would naturally like to hear from an average sample. The work has not progressed to a point where this is obtainable, however.

A NEW RAPID PRESUMPTIVE TEST FOR BACILLUS COLI IN WATER

By G. R. SPALDING

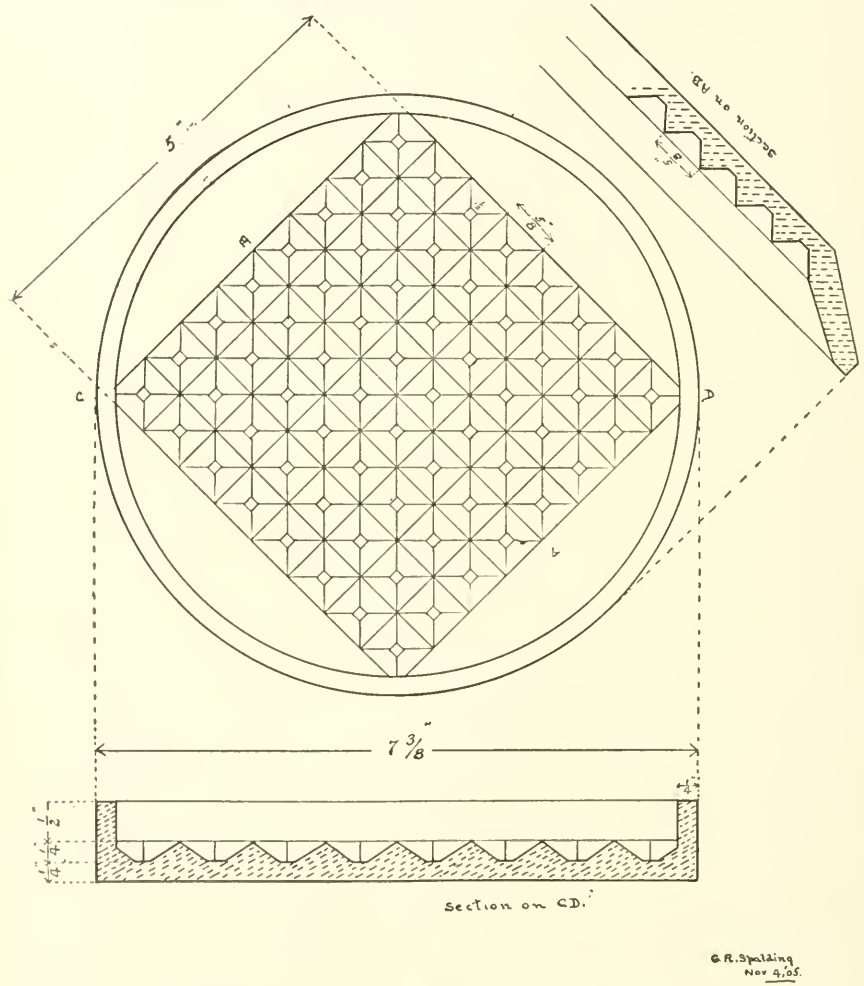
Superintendent of the New Milford plant of the Hackensack Water Company

In the control of municipal filter plants it is important to determine, in the shortest possible time, the extent to which *Bacillus coli* and other gas-producing organisms have been removed. For this purpose the "Indented Plate," represented in the accompanying figure, has been devised.

B. coli and other sewage bacteria grow most rapidly in liquid media at temperatures slightly under 40° C. On the other hand, solid media are much better adapted to exact quantitative work than the ordinary fermentation tube. In the process here described the attempt has been made to combine the advantages of both solid and liquid media so as to obtain exact quantitative results in the shortest possible time. This has been accomplished by the use of a large glass plate with sixty-four small indentations, the design of which is shown in the figure. Among the cavities or indentations from 1 to 5 c.c. of the water, diluted and mixed with litmus sugar broth, is carefully distributed. As short a period of incubation as eight hours amply suffices to differentiate those cavities in which acid-forming organisms are present. The process is, in fact, the old dilution method of Miquel, so modified as to be of use on a practical scale.

In the control of the mechanical filter plant at New Milford the author has used the indented plate in testing for acid formation, gas formation, and gas ratio in the unfiltered and filtered waters in the following manner: a concentrated lactose broth, five times as strong as ordinary broth, is prepared and tubed. One c.c. of this broth and 1 c.c. of the river water are added to 9 c.c. of sterile water, 1 c.c. of litmus added, and the mixture poured into the plate. Violent, lateral agitation is necessary to distribute the solution evenly in the cavities. With the filtered effluent, 5 c.c. of the sample are diluted with 5 c.c. of sterile water, and 1 c.c. each of broth and litmus added. Plates show formation of acid in eight hours, and, if made late in the afternoon,

are ready to be reinoculated into fermentation tubes the next morning. Any cavities showing acid formation are thus reinoculated, so that the tubes shall be ready for examination for gas on the following morning. The number of cavities showing acid formation has proved to be of considerable value in this work as an indication of the degree of puri-



fication, but only a small percentage of such acid cavities subsequently give typical gas formation. With the use of a certain amount of personal equation in adapting the method to suit the requirements of the work in hand, it is the opinion of the author that the indented plate will be found of considerable value in following the bacterial changes in water filtration and in other processes.

THE DISTRIBUTION OF LOADS ON STRINGERS OF HIGHWAY BRIDGES CARRYING ELECTRIC CARS[1]

By F. P. McKIBBEN

In many highway bridges which carry a street railway track the rails are laid directly upon a layer of planking, which in turn rests upon the track stringers, as shown in Figure 1. This is a common method of supporting the rails on old bridges originally designed to carry only ordinary highway traffic, over which street railway tracks were subsequently laid. If the floor planking is laid transversely, it will act as a series of transverse beams and will thereby transfer part of the rail

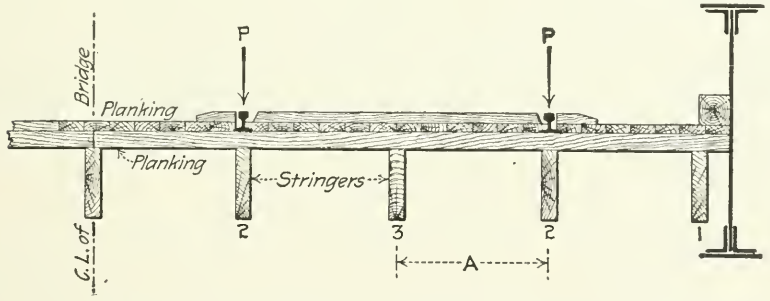


Fig. 1.—Transverse Section of Floor of Old Highway Bridge Carrying Electric Railway Tracks.

load to stringers not immediately under the rail, and correspondingly reduce the load on the rail stringers. The distribution of the wheel loads over the floor stringers of such a bridge is the subject of the following study:

Given: P, the load on each rail, assumed at the centre of the panel.

L, the panel length.

A, the distance, centre to centre, of stringers.

I, moment of inertia of the cross section of the planking over which the loads P are distributed.

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[1] Reprinted from Engineering News, April 12, 1906, 55, No. 15.

I_1, moment of inertia of each of the stringers.

E, modulus of elasticity of wood.

Required: F_1, F_2, F_3, the amounts of load borne by stringers 1, 2, 3, respectively.

We have the three unknown quantities, F_1, F_2, F_3, and must, therefore, have three independent equations. These are deduced as follows:

$$2F_1 + 2F_2 + F_3 = 2P \quad \ldots\ldots \quad (1).$$

A second equation may be obtained by equating the difference between the deflections of the points 1 and 2 of the planking and the difference between the deflections of the same points of stringers 1 and 2. The third equation may be obtained by equating the difference between the deflections of the points 2 and 3 of the planking and the difference between the deflections of the same points of stringers 2 and 3.

The effect of the upper layers of planking will be neglected. The effect of the lower layer will be assumed to be as shown in Figure 2 Taking the lower layer of planking to be a beam with free ends at stringer 1, it will be sufficient, because of symmetry about 3, to consider only the section 3-1, represented by a cantilever beam fixed at 3 and loaded at 2 (by P and F_2) and at 1 (by F_1). Then the following expressions hold:

Deflection of point 2, with reference to point 3:

$$\text{Downward, due to load } (P - F_2) \text{ at point 2, } = \frac{(P - F_2)\,A^3}{3\,E\,I}.$$

$$\text{Upward, due to load } F_1 \text{ at point 1, } = \frac{5\,F_1\,A^3}{6\,E\,I}.$$

$$\text{Resultant, downward, } d_{23} = \frac{A^3}{6\,E\,I}(2\,P - 2\,F_2 - 5\,F_1).$$

Deflection of point 1, with reference to point 3:

$$\text{Downward, due to load } (P - F_2) \text{ at point 2, } = \frac{5\,A^3\,(P - F_2)}{6\,E\,I}.$$

$$\text{Upward, due to load } F_1 \text{ at point 1, } = \frac{8\,F_1\,A^3}{3\,E\,I}.$$

$$\text{Resultant, downward, } -d_{13} = \frac{A^3}{6\,E\,I}(5\,P - 5\,F_2 - 16\,F_1).$$

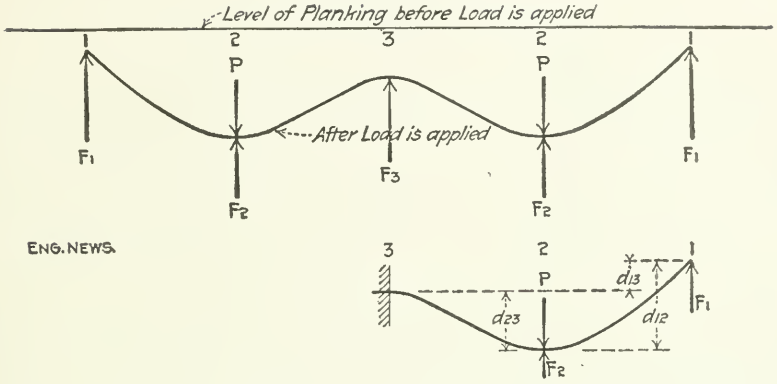

FIG. 2.—DIAGRAM OF STRINGER LOAD DISTRIBUTION ON HIGHWAY BRIDGE FLOOR CARRYING ELECTRIC RAILWAY TRACK

The difference in deflection of the planking at points 1 and 2 is (see Figure 2):

$$d_{12} = d_{23} + d_{13} = \frac{A^3}{6\,E\,I}(3\,F_2 - 3\,P + 11\,F_1).$$

Equating this with the difference in deflection of stringers 1 and 2 at the centre of the panel, we have

$$\frac{L^3}{8\,I_1}(F_2 - F_1) = \frac{A^3}{I}(3\,F_2 - 3\,P + 11\,F_1) \quad \ldots\ldots \quad (2),$$

the value of the modulus of elasticity E being the same for stringer and planking.

Similarly, the expression above given for d_{23} (the difference of deflection between points 2 and 3) may be equated to the difference of deflection in the corresponding stringers. This gives the third equation required:

$$\frac{L^3}{8\,I_1}(F_2 - F_3) = \frac{A^3}{I}(2\,P - 2\,F_2 - 5\,F_1) \quad \ldots\ldots \quad (3).$$

The solution of equations (1), (2), and (3) gives the following values for F_1, F_2, and F_3:

$$F_1 = \frac{2\,P\,L^3\,I\,(20\,A^3\,I_1 + L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

$$F_2 = P - \frac{P\,L^3\,I\,(128\,A^3\,I_1 + 3\,L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

$$F_3 = \frac{2\,P\,L^3\,I\,(88\,A^3\,I_1 + L^3\,I)}{448\,A^6\,I_1^2 + 272\,A^3\,L^3\,I\,I_1 + 5\,L^6\,I^2}.$$

The accompanying table shows some values of the loads F_1, F_2, and F_3 as given by the above formulas. An examination of the table will show that an axle load of 15,000 pounds has been assumed on a panel length of 13 feet, with stringers spaced 30 inches apart. The thickness of the planking has been taken as 3 inches, and the axle load has been assumed to be distributed by the rails over 20 inches of the planking.

The table shows, for example, that for stringers 4 x 14 inches 7.2 per cent. of the axle load is carried by each outside stringer, 30 per cent. by each of the stringers under the rails, and 25.6 per cent. by the stringer under the centre of the track.

The above computations have been made to show how the loads are distributed under the most favorable circumstances. Oftentimes the planking is so decayed that it transfers little load to the adjacent stringers, and the stringers directly under the rails carry practically the entire load.

If the loads P are placed at the *end of the panel* instead of at the centre, the planking has no effect in distributing the loads over the adjacent stringers, and the stringers directly under the rails carry the entire track load.

In designing a new structure of this kind, the stringers under the rails should be made of sufficient size to carry the track loads without any assistance from the adjacent stringers.

TABLE SHOWING DISTRIBUTION OF LOADS ON STRINGERS OF HIGHWAY BRIDGES CARRYING ELECTRIC CARS

Thickness of planking.	Distribution of load on planking.	Size of stringers.	Spacing of stringers. A.	Span of stringers. L.	Total load per axle $2P$ (pounds).	Load Carried by Each Stringer (Pounds).			Per Cent. of Total Axle Load Carried by Each Stringer.		
						F_1.	F_2.	F_3.	Outside stringer.	Stringer under each rail.	Centre stringer.
3″	20″	3 x 14″	30″	156″	15,000	1,195	4,316	3,978	8.0	28.8	26.4
3″	20″	4 x 14″	30″	156″	15,000	1,088	4,494	3,836	7.2	30.0	25.6
3″	20″	6 x 14″	30″	156″	15,000	941	4,788	3,542	6.3	31.9	23.6

TESTS ON A VACUUM SWEEPER

By EDWARD F. MILLER

The following tests were conducted by the fourth-year students as a part of the regular assigned work of the Engineering Laboratories of the Massachusetts Institute of Technology, and were made under the direction of Mr. A. H. Smith of the instructing staff of the laboratory.

The apparatus was presented by the Sanitary Devices Company. It consisted of a double-acting vacuum pump 8 inches diameter by 12 inches stroke, having a piston rod 1¼ inches in diameter; two dust removing tanks (one wet and one dry); about 100 feet of rubber pipe 1 inch inside diameter; an inrush sweeper made by the Sanitary Devices Company; and a D. T. Kenney sweeper. These sweepers are designated in the tests which follow as Inrush and Vacuum.

Indicators were attached to the air pump, and the power used in the pump cylinder was calculated from cards taken during each test.

All of the tests were conducted in practically the same way. In some of the first tests dirt, meal, flour, etc., were used on the carpet, but later on a fine sand resembling street dust was used. This sand was found during the excavation of the East Boston Tunnel. It was used in all of the tests quoted in this article.

A Kazak rug 3 feet 6 inches by 9 feet was charged with a certain amount of this sand by sprinkling the sand on the rug and then thoroughly treading it in. The rug was then weighed on a special scale known as a silk scale. This scale was read to the nearest one-fourth ounce. The rug was then swept with one sweeper for a period of ten minutes, weighings of the rug being made at the end of each two-minute period.

The rug was again charged with sand till it weighed about the same as before, and then swept in the same way with the other sweeper.

From day to day the order in which the sweepers were used was changed. It will be noticed that the ten-minute sweeping was not

sufficient to remove all of the sand added, as the carpet gradually grew heavier.

As might be expected, some were more expert in using the sweepers than others. This was particularly noticeable with the Inrush sweeper, which on account of its broader base was more difficult to keep to an even bearing on the carpet than the Vacuum sweeper with its very

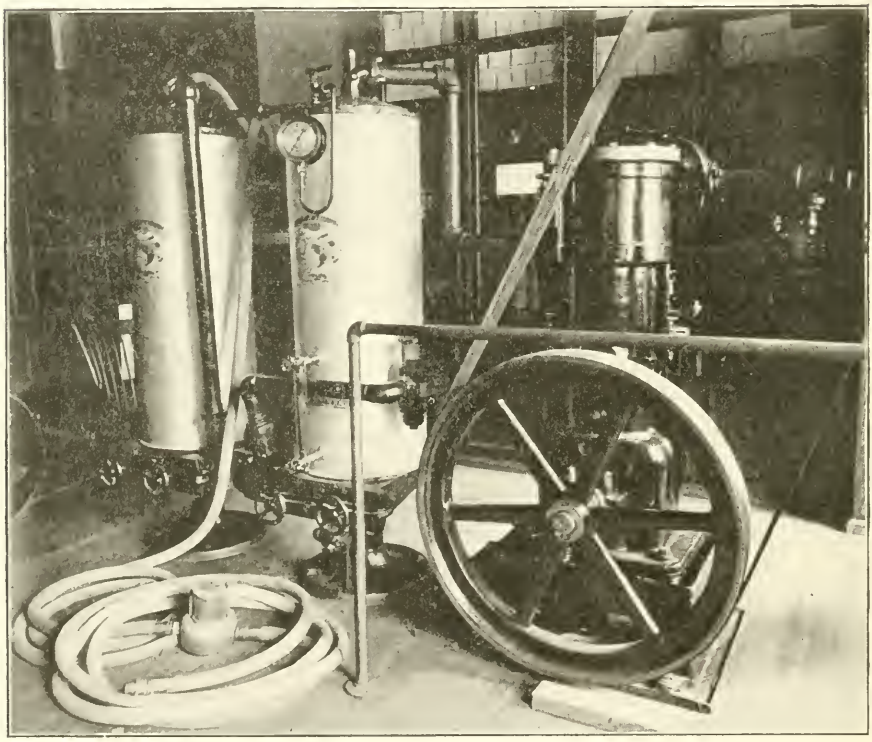

FIG. 1. — VACUUM PUMP AND DUST TANKS

narrow base. The Vacuum sweeper had a slot $14\frac{3}{4}$ inches long and $\frac{1}{16}$ inch wide.

The opening for inrush of air in the Inrush sweeper was .05 inch wide and $11\frac{5}{8}$ inches long. The opening beyond was $11\frac{5}{8}$ inches by $\frac{5}{16}$ inch. The bridge between the two openings was about .04 inch above the plane of the face of the sweeper. The foot of the sweeper was $1\frac{3}{4}$ inches wide.

FIG. 2. — VACUUM AND INRUSH SWEEPERS

SUMMARY

Series.	DIRT REMOVED PER MINUTE PER CUBIC FOOT OF FREE AIR.		DIRT REMOVED PER MINUTE PER HORSE POWER OF AIR CYLINDER.		AVERAGE VACUUM IN INCHES.		HORSE POWER.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
I_0	.00185	.00254	.0438	.0631	12.73	12.11	2.018	2.008
II_0	.00154	.00182	.0292	.0364	14.00	13.49	2.675	2.658
III_0	.00061	.00132	.0142	.0314	12.68	12.30	2.068	2.073

An investigation carried on as thesis work by Messrs. Patterson and Phelps showed that the most economical vacuum for each sweeper was between 15 inches and 16 inches. In all of their work the sweeper was held in a carriage so that it bore perfectly on the carpet and gave the best condition possible for efficient sweeping. They found that the force needed to push the two sweepers over a carpet was practically the same for one sweeper as for the other. Their experiments were made on a Wilton carpet and the Kazak rug.

TESTS ON VACUUM CLEANERS

I_0. Tests 7-28, vacuum = 12.0"-12.5"

No.	Revolutions per Minute.		Vacuum.	
	Vacuum.	Inrush.	Vacuum.	Inrush.
	1	2	3	4
7	108	113	12.2	12.2
8	117	115	12.2	12.3
9	121	120	12.5	12.5
10	124	116	12.4	11.8
13	120	121	13.7	12.7
14	124	125	13.2	11.7
16	120	121	13.0	12.1
17	124	121	12.8	12.4
19	122	120	13.1	12.1
20	121	124	12.7	12.2
21	120	120	13.1	11.8
22	120	120	12.5	11.8
23	120	121	13.1	12.5
24	120	120	12.3	11.8
25	120	120	13.0	12.6
26	121	121	13.2	12.8
28	122	122	11.4	10.6
Average	120.3	120.0	12.73	12.11

I_0. Tests 29-44, vacuum = 13.5"-14.0"

No.	Revolutions per Minute.		Vacuum.	
	Vacuum.	Inrush.	Vacuum.	Inrush.
	1	2	3	4
29	147	146	13.1	12.4
30	143	143	13.0	12.9
31	144	148	13.6	12.6
32	147	147	13.9	13.2
33	145	146	14.0	13.5
34	140	140	14.0	13.5
35	144	144	14.5	14.0
36	146	146	14.5	13.7
37	141	140	14.2	13.9
38	147	146	14.4	13.6
39	145	144	14.8	14.0
40	144	143	13.9	13.5
41	145	145	14.4	13.8
42	145	145	13.9	13.7
43	147	147	14.1	13.5
44			13.9	14.2
Average	144.7	144.7	14.00	13.49

TESTS ON VACUUM CLEANERS

VACUUM.

No.	Weight of carpet plus the dirt. Pounds.	Dirt removed in first two minutes. Pounds.	Dirt removed in second two minutes. Pounds.	Dirt removed in third two minutes. Pounds.	Dirt removed in fourth two minutes. Pounds.	Dirt removed in fifth two minutes. Pounds.
	5	6	7	8	9	10
7	28.42	.77	.30	.17	.19	.11
8	28.31	.41	.32	.19	.14	.10
9	29.78	.40	.11	.11	.08	.06
10	30.62	.41	.12	.06	.09	.09
13	29.97	.33	. .	. .	. .	. .
14	30.86	.48	.41	.53	.23	.22
16	30.44	.56	.23	.12	.12	.11
17	30.55	.36	. .	. .	. .	. .
19	29.22	.22	.11	.07	.05	.07
20	30.22	.41	. .	. .	. .	. .
21	30.28	.28	.16	.12	.09	.08
22	30.55	.30	.11	.11	.06	.03
23	31.08	.44	.17	.13	.08	.07
24	30.69	.27	.14	.20	.06	.05
25	31.48	.34	. .	. .	. .	. .
26	31.69	.31	.17	.11	.09	.09
28	32.52	.39	.22	.10	.11	.07
29	30.25	.42	.06	.06	.06	.06
30	30.40	.24	.11	.15	.13	.06
31	31.08	.34	.09	.09	.08	.06
32	31.50	.31	. .	. .	. .	. .
33	31.76	.31	. .	. .	. .	. .
34	31.50	.22	. .	. .	. .	. .
35	31.91	.27	.08	.05	.06	.06
36	33.25	.22	.13	.09	.09	.09
37	33.94	.38	.18	.16	.09	.10
38	34.44	.33	.25	.11	.14	.07
39	34.59	.41	.16	.12	.09	.09
40	35.05	.36	.17	.14	.09	.08
41	35.25	.41	.22	.14	.17	.12
42	37.38	.25	.13	.09	.08	.08
43	36.12	.38	.16	.14	.12	.03

INRUSH.

No.	Weight of carpet plus the dirt. Pounds.	Dirt removed in first two minutes. Pounds.	Dirt removed in second two minutes. Pounds.	Dirt removed in third two minutes. Pounds.	Dirt removed in fourth two minutes. Pounds.	Dirt removed in fifth two minutes. Pounds.
	11	12	13	14	15	16
7	28.34	.41	.47	.31	.34	.28
8	28.39	.47	.17	.20	.14	.19
9	29.72	.64	.27	.20	.14	.11
10	30.66	.25	.11	.19	.08	.25
13	29.94	.37	.33	.19	.17	.09
14	30.88	.53	.19	.20	.09	.17
16	30.20	.76	.36	.29	.28	.25
17	30.59	.50	.44	.34	.22	.28
19	29.22	.44	.23	.13	.16	.10
20	30.22	.39	. .	. .	. .	. .
21	30.28	.34	.25	.17	.17	.20
22	30.58	.36	.14	.17	.10	.15
23	31.11	.47	.20	.17	.20	.22
24	30.69	.22	.14	.11	.09	.08
25	31.48	.41	. .	. .	. .	. .
26	31.72	.38	.26	.16	.17	.14
28	32.55	.36	.13	.20	.09	.13
29	30.25	.44	.30	.19	.17	.09
30	30.40	.20	.13	.13	.11	.10
31	31.08	.41	.30	.08	.16	.19
32	31.60	.22	. .	. .	. .	. .
33	31.76	.24	. .	. .	. .	. .
34	31.50	.36	.13	.16	.15	.11
35	31.85	.36	.17	.11	.09	.08
36	33.25	.51	.25	.19	.16	.11
37	33.97	.22	.25	.16	.12	.09
38	34.42	.42	.27	.29	.15	.14
39	34.61	.50	.20	.12	.19	.12
40	35.05	.42	.25	.16	.16	.17
41	35.24	.45	.22	.17	.13	.12
42	35.38	.33	.17	.16	.09	.13
43	36.13	.20	.11	.20	.06	.09

No.	Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air per Minute.		Horse Power of Pump.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
	17	18	19	20	21	22	23	24	25	26
7	1.53	1.81	.086	.097	84.7	85.3	. .	. .	1.79	1.88
8	1.17	1.17	.060	.060	82.8	86.2	. .	. .	1.95	1.95
9	0.76	1.36	.036	.067	84.7	83.3	. .	. .	2.13	2.03
10	0.78	0.88	.038	.047	83.6	80.2	. .	. .	2.07	1.87
13	0.69	1.15	.031	.053	82.7	83.6	. .	. .	2.20	2.17
14	1.18	1.89	.053	.091	84.3	85.9	. .	. .	2.07	2.21
16	1.14	1.97	.057	.102	82.5	82.7	. .	. .	2.00	1.93
17	0.95	1.78	.046	.089	84.8	83.6	. .	. .	2.06	2.01
19	0.52	1.06	.025	.055	83.8	82.2	. .	. .	2.12	1.94
20	0.84	1.41	.042	.066	83.6	86.2	. .	. .	2.01	2.13
21	0.73	1.14	.036	.057	80.9	82.8	. .	. .	2.06	2.01
22	0.61	0.92	.030	.047	81.2	84.4	. .	. .	2.01	1.98
23	0.89	1.27	.042	.058	83.8	85.5	. .	. .	2.14	2.18
24	0.72	0.64	.035	.032	82.2	83.3	. .	. .	2.04	2.02
25	0.85	1.10	.041	.052	81.7	82.8	. .	. .	2.07	2.10
26	0.78	1.11	.037	.052	83.4	83.2	. .	. .	2.12	2.13
28	0.89	0.91	.050	.052	82.6	83.9	. .	. .	2.78	1.76
. .	150.3	2.157	.745	1.077	. .	. .	. .	. .	. .	. .
Av.	0.884	1.269	.0438	.0632	83.14	83.83	.00106	.00151	2.018	2.008
					Free air per minute,		.00185	.00254		

No.	Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air per Minute.		Horse Power of Pump.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
	17	18	19	20	21	22	23	24	25	26
29	0.67	1.19	.026	.047	54.8	57.7	. .	. .	2.55	2.50
30	0.69	0.67	.028	.029	54.1	55.0	. .	. .	2.48	2.34
31	0.66	1.14	.025	.042	51.9	56.4	. .	. .	2.67	2.72
32	0.97	0.82	.035	.030	51.7	54.8	. .	. .	2.80	2.78
33	0.79	0.81	.028	.029	51.5	54.0	. .	. .	2.78	2.75
34	0.47	0.91	.018	.034	49.3	51.0	. .	. .	2.65	2.68
35	0.51	0.81	.020	.029	49.5	51.8	. .	. .	2.59	2.79
36	0.62	1.21	.022	.046	48.6	52.7	. .	. .	2.79	2.64
37	0.91	0.84	.035	.032	47.6	49.5	. .	. .	2.61	2.59
38	0.91	1.27	.031	.047	50.8	54.4	. .	. .	2.90	2.70
39	0.87	1.13	.031	.042	48.1	50.4	. .	. .	2.81	2.68
40	0.85	1.15	.032	.043	51.3	53.7	. .	. .	2.65	2.69
41	1.06	1.09	.042	.041	48.6	50.8	. .	. .	2.52	2.67
42	0.63	0.88	.024	.034	52.6	52.9	. .	. .	2.65	2.58
43	0.83	0.67	.031	.025	50.8	55.3	. .	. .	2.61	2.67
44	1.06	0.90	.039	.032	52.0	50.4	. .	. .	. .	. .
Av.	0.781	0.968	.0292	.0364	50.83	53.18	.00154	.00182	2.675	2.658

Tests on Vacuum Cleaners

III. { No dirt added; one-half rug with each sweeper

No.	Revolutions per Minute.		Vacuum.		Dirt Removed in Ten Minutes. Pounds.		Pounds Dirt per Horse Power per Minute.		Cubic Feet Air at Vacuum per Minute.		Pounds Dirt per Cubic Foot Air.		Horse Power of Pump.	
	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.	Vacuum.	Inrush.
11	120	120	13.2	13.0	.25	.80	.0112	.0361	85.8	84.4	.0029	.0095	2.24	2.22
15	121	121	12.7	12.1	.43	.56	.0209	.0276	82.0	82.8	.0053	.0068	2.06	2.03
18	120	121	12.3	12.2	.27	.67	.0137	.0322	82.4	83.9	.0033	.0080	1.97	2.08
27	120	123	12.5	11.9	.22	.58	.0110	.0296	82.4	83.5	.0027	.0070	2.00	1.96
	481	485	50.7	49.2	1.17	2.61	.0568	.1255	332.6	334.6	.0142	.0313	8.27	8.29
Average per minute	120.3	121.3	12.68	12.30	.293	.653	.0142	.0314	83.15	83.65	.000355	.000783	7.068	2.073
							Free air per minute,		48.00	49.40	.000610	.00132		

BOOK REVIEWS

Reinforced Concrete[1]

This little book, which unfortunately has been written by a graduate of the Institute, illustrates the danger of running into print without taking good advice. The author states that his object has been to produce a reference handbook adapted to the wants of the architect, engineer, and contractor; and that the treatment "has been carried out along well-known formulæ based on the theory of elasticity, but modified by the usual assumptions, . . . not upon empirical formulæ based upon experiments," and he hopes that the volume will "tend to do away with the use of some of the empirical formulæ and rule-of-thumb methods." Unfortunately the book, with its tables and computations, is based upon entirely incorrect fundamental mechanical principles, which fact makes it not only valueless, but unsafe. Two illustrations will suffice to show the truth of this statement. In computing beams (pages 42, 43), the writer proceeds as follows: He takes the neutral axis at a certain point and then assumes the entire bending moment to be carried by the concrete beam, neglecting the portion below the rods and taking no account of the stress in the steel. This gives him for test beam No. 1 the compressive stress at the extreme top of the beam, 3,700 pounds per square inch. He then takes the same total bending moment and places it equal to the moment of the stress in the rods alone, taken about the neutral axis, with no allowance for the concrete, which gives him 55,000 pounds per square inch in the rods. He then assumes that the horizontal layer of concrete for a height equal to the diameter of the rods stretches the same as the rods, and that, therefore, the tensile stress in this concrete is 4,500 pounds per square inch! This method of computation, as any one familiar with the elements of the beam theory will see, is absurd.

His treatment of shear is equally erroneous. He first states that the vertical shearing force on any section is distributed over the entire section in such a way that the strain on the steel equals the strain on

[1] F. D. Warren: A Handbook of Reinforced Concrete for Architects, Engineers, and Contractors. New York: D. Van Nostrand, 1906. 271 pp.

the concrete. In other words, the stress of the concrete is uniform over the entire area of the concrete. He then says that the longitudinal shear varies from the neutral axis outward, diminishing from a maximum at the neutral axis to zero at the extreme fibers. He has evidently forgotten the principle that on any two planes at right angles to each other the shearing forces parallel to a third plane which is perpendicular to both have equal intensities. But, worse still, he then proceeds to compound these two unequal (!) shearing forces on different planes, and obtains a resultant shearing force on a plane making an angle of 61° with the vertical!

These two illustrations are quite sufficient to give an idea of the character of the book and of the unreliability of the author's reasoning. Further criticism or mention is unnecessary, for any one who makes such fundamental errors as the above is unworthy of further attention. Mr. Warren was taught the theory of beams, but he has evidently not mastered the first principles. It is very much to be regretted, for his own sake, that he should have rushed into print, and equally to be regretted that any publisher should have been advised to print the book.

GEORGE F. SWAIN.

THE POLARISCOPE[1]

IT will be well to quote from the preface of this book as follows:

"The immense importance of the sugar industry in world economics has forced the development of the polariscope into a sugar-testing instrument of high efficiency. Comparatively few practicing chemists are familiar with any other application of the useful laboratory tool.

"Many books have been written on commercial saccharimetry, but it is only by hunting through the whole mass of literature of analytic chemistry that occasional instances can be found of the application of the polariscope in general laboratory practice.

"Landolt's great work is the only one devoted to a complete treatment of the subject of polarimetry, but that is, in the main, a book for the physical chemist and trained investigator in pure science.

"Hence I have ventured to write a simple introductory treatise, not

[1] G. W. Rolfe: The Polariscope in the Chemical Laboratory. An Introduction to Polarimetry and Related Methods. New York: Macmillan, 1905. 7 + 320 pp., 37 il., tables, 12mo.

a complete manual of polarimetry by any means, but one explaining in an elementary way fundamental principles and their application in general laboratory practice.

"Naturally, I have devoted much space to methods in use in sugar manufacture, but have also described those used in brewing, the starch industries, and food and drug analysis as well. It has seemed best to introduce outlines of some technical processes and factory methods of chemical control to make the subject clearer. I have also overstepped the strict bounds of polarimetry to explain methods obviously accessory to many determinations.

"A sketch of the use of the polariscope in pure science is given in view of the great possibilities of the instrument in that field."

In this preface the author has well stated what his book is intended to cover.

The subjects of "The Polariscope," "The Saccharimeter," and "Accuracy of Saccharimeter Measurements" have been very carefully and scientifically considered.

The technical information given in these various chapters does not differ materially from what has been presented in other books, save in the original manner in which it is brought out.

The subjects, however, of the following chapters — "Notes Applying to Special Instruments," "Polarization of Cane Sugar — General Commercial Methods," "Sugarhouse and Refinery Methods," "Starch and Starch Products," "Miscellaneous Saccharine Products" — are handled in a manner only possible by one who has had considerable experience in technical and industrial work.

There is much information in these chapters which has never before been presented in any of the works on sugar, and is given by the author as the result of years of experience in technical and industrial work. Many of the difficulties which confront a technical chemist in work with the polariscope and saccharimeter, and which have never been alluded to in any other works, are discussed at some length, and it is possible for one with a technical training, but without experience with these instruments, to become thoroughly experienced in their use if he but follow closely the suggestions as given by the author.

The tables, which occupy a number of pages, have been selected with great care for the use of sugar and starch chemists, and form a valuable part of the book.

The book is one which can be heartily recommended to the technical

men who are obliged to use the polariscope or saccharimeter and who have not had a thorough, practical experience with them, and should be welcomed as a distinct addition to sugar literature, showing much original thought. L. W. P.

A Text-Book on Electric Railways[1]

This book is written as a text-book for the use of college students and as a reference book for engineers. Unfortunately, however, it does not seem to meet the needs of either class of readers. As a text-book it fails in that the subjects treated are largely those which are seldom discussed in the classroom; on the other hand, some of the subjects discussed are so elementary in character that they should be understood by the students before they begin to study the railway problem. As a reference book it fails in that it treats subjects which are well understood by engineers.

The book deals with railway motors, both those using direct and those using alternating currents, and it treats also of controllers, brakes and braking, car bodies, trucks, and minor details. The chapters dealing with units, instruments, recording apparatus, and curve plotting are incomplete, however, and lacking in the details that would give them value either to the student or to the engineer.

The chapter dealing with train performance is very good so far as it goes, but for students lacks much in regard to details which will need to be supplied by the lecturer.

In regard to controllers and also in dealing with brakes and braking we miss the details of operation, and the diagrams furnished are too small for practical use. The troubles of controllers are of considerable importance both to the student and the engineer, and it is unfortunate that the notes on this subject are not more extended.

In its entirety the book makes very good reading for a man who wishes to obtain a superficial idea of the method of planning an electric railway and some information as to the operation of the component parts of electric cars. But much of the book is elementary, and it is not likely to be found useful by either the student or the engineer who

[1] S. W. Ashe and J. D. Keiley: Electric Railways Theoretically and Practically Treated. New York: Van Nostrand, 1905. 284 pp., 172 il., 6 pl., 12mo.

wishes to go deeply into matters of construction and operation of electric railways. HENRY D. JACKSON.

NOTES ON ELECTRO–CHEMISTRY[1]

THE object of this work is, as stated in the preface, "to offer a general survey of the subject, to serve as an introduction to its study, and to aid in the securing of a proper understanding and appreciation of the work along individual lines."

Chapters I and II are devoted to very general subjects. Chapter I deals with inductive and deductive reasoning, the laws of the conservation of mass and of energy, and the C. G. S. system of units; while Chapter II gives a historical sketch of the growth of the knowledge of electricity from the earliest times down to radio-activity, and explains the units used in electrical measurements.

Chapter III, treating of electro-chemistry from a historical standpoint, and Chapter IV, on "Electrolytic Dissociation," are exceedingly brief. Electromotive force, for instance, is disposed of in a page and a half. This fact alone shows that the treatment of this subject must be inadequate to any purpose whatever.

Chapter V, on "Electro-Analysis," deals only with the principles underlying this subject, omitting all specific directions for carrying out the determination of any one element. The presentation cannot be said to be perspicuous, and is not always correct; for instance, on page 75 where the resistance of a cell is computed and incorrectly called the "reverse electromotive force."

Chapter VI, on "Electrotechnology," includes short accounts of metal refining, electroplating, the production of chlorine and alkali hydrates, and electric furnace products.

At the heading of each chapter is a bibliography of works dealing with the subject treated in that chapter.

This work could be of little use as an introduction to theoretical electro-chemistry, but it does point out the principal industrial applications of this science, and to this extent could be a guide to further reading.

M. DEK. THOMPSON.

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[1] Notes on Electro-Chemistry. By F. G. Wiechmann. New York: McGraw Publishing Co., 1906. ix + 145 pp.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BOSTON, MASS.

HENRY S. PRITCHETT, President

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THE TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS

Vol. XIX SEPTEMBER, 1906 No. 3

PROCEEDINGS OF THE SOCIETY OF ARTS

FORTY-FOURTH YEAR, 1905-1906

Boston, May 10, 1906.

The 624th regular meeting and the 45th annual meeting of the Society of Arts was held at the Institute, Room 22, Walker Building, on Thursday evening, May 10, 1906, at eight o'clock. Professor Gaetano Lanza presided. One hundred and thirty persons were present.

The election of an Executive Committee for the ensuing year was the first item of business. The nominations sent in by the Nominating Committee were as follows: Mr. George W. Blodgett, chairman, Colonel E. H. Hewins, Mr. James P. Munroe, Professor James F. Norris, Mr. Grosvenor T. Blood. The Secretary was empowered to cast one ballot for these gentlemen. For Secretary, the name of Professor Walter S. Leland was presented, and he was elected for the ensuing year.

The chairman then presented Mr. Herbert O. Keay, who read an interesting and instructive paper on "The Practical Operation of a Dynamometer Car in Establishing Locomotive-Tonnage Rating." The paper described in detail the investigations carried on by the speaker for the Boston and Maine Railroad.

After some discussion the meeting adjourned, the chairman first expressing the thanks of the Society to the speaker for his excellent paper.

SAMUEL C. PRESCOTT, *Secretary.*

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE PRESENTED AT THE FORTY-FOURTH ANNUAL MEETING OF THE SOCIETY, MAY 10, 1906

The first meeting of the SOCIETY OF ARTS for the present year was held on October 12, 1905. Thirteen meetings have been held, with an average attendance of one hundred and seventeen. During the past year the interest awakened in the Society and manifest for several years has been continued, not only by the members, but especially by the public at large and many of the students of the Institute. The attendance of the latter when papers of technical interest have been presented was especially gratifying. The range of the subjects which have been presented has been a wide one, and as a consequence nearly all the students have had the opportunity to hear a paper on some subject of professional interest.

The following papers have been read:

"Disposal of City Sewage," by Professor Charles-Edward A. Winslow, Biologist-in-Charge of the Research Station and Sewage Experiment Laboratory.

"Brown-tail and Gypsy Moths: Their Life Histories, and Some Suggestions for Their Suppression," by Mr. William Lyman Underwood.

"Submarine Signaling," by Mr. Henry R. Gilson.

"Recent Researches on the Canals of Mars," by Professor Percival Lowell, Director of the Astronomical Observatory at Flagstaff, Arizona.

"The Treatment of the Black Sands of the Pacific Coast by the United States Geological Survey," by Professor Robert H. Richards, of the Institute.

"The American Indian Folklore," by Professor Alexander F. Chamberlain, of Clark University.

"Hydraulic Mining in British Columbia and Alaska," by Mr. Howard W. Dubois, Mining Engineer of Philadelphia.

"Causes and Effects of River Capture," by Professor Douglas W. Johnson, of the Institute.

"Shoddy, or the History of a Woolen Rag," by Mr. Henry G. Kittredge, Editor of the *Textile American*.

"The Chemistry of Cellulose as Applied to Textile Fibres, Mercerized Cotton, Artificial Silk, and Horse Hair," by Professor William H. Walker, of the Institute.

"The American Bison, Our Grandest Native Animal," by Mr. Ernest Harold Baynes.

"The Rationale of the Industrial-Betterment Movement," by Mr. H. F. J. Porter, of New York.

"Practical Operation of a Dynamometer Car in Establishing Locomotive-Tonnage Rating," by Mr. Herbert O. Keay.

The number of members of the Society has remained practically the same as last year. Fifteen members have resigned, two have died and two have not been heard from, and the number of new members elected to Associate Membership has been fourteen, leaving the total membership three hundred and fifty-eight.

The TECHNOLOGY QUARTERLY has continued its publication under the editorship of Dr. Robert P. Bigelow, with the advice and counsel of the Publication Committee of the Society. In addition to the Proceedings of the Society twenty-five papers and twenty-five book reviews have been published. Among the papers published were some of special interest.

Professor John Bigelow, Jr., has published a paper on "Modern Language Teaching, with Special Reference to Pronunciation and Conversation."

Professor Hovgaard has published two papers, one on "The Cruiser," and another, "The Sea-Going Battleship."

Mr. Henry R. Gilson has published a paper on "Submarine Signaling."

Mr. F. F. Fowle a paper on "Railway Telephone Service, the Cost of Line Construction."

Mr. William Atkinson a paper on "Orientation of Buildings and Streets in Relation to Sunlight."

The different departments have contributed papers as follows: Biological Department, four papers; Chemical Department, three papers; Electrical Engineering Department, two papers; Geological

Department, two papers; Naval Architecture Department, two papers; Modern Languages Department, one paper.

Respectfully submitted,

GEORGE W. BLODGETT,
JAMES P. MUNROE,
CHARLES T. MAIN,
E. H. HEWINS,
S. C. PRESCOTT,
} *Executive Committee.*

A SYSTEM OF QUALITATIVE ANALYSIS FOR THE COMMON ELEMENTS[1]

INTRODUCTION: OUTLINE OF THE INVESTIGATION
PART I. PREPARATION OF THE SOLUTION
PART II. ANALYSIS OF THE SILVER, COPPER, AND TIN GROUPS

By ARTHUR A. NOYES and WILLIAM C. BRAY

INTRODUCTION: OUTLINE OF THE INVESTIGATION

This investigation was undertaken for the purpose of studying the processes of qualitative analysis in general use, with reference to their effectiveness in enabling small quantities of each of the more common elements or element-groups to be detected in the presence of any of the other elements, and for the purpose of selecting the methods best adapted to this end and of improving them wherever desirable and practicable. In spite of the vast number of text-books on qualitative analysis in which more or less different processes are recommended, there seems to have been made in recent years no exact systematic study of the relative effectiveness of the separations or of the delicacy of the final tests. It has seemed to us, therefore, worth while to make a detailed investigation of this kind; and as a result of it to develop, if possible, a system of analysis which will enable a quantity of any element as small as one or two milligrams to be detected in any mixture. Effort will also be made to employ only such processes as enable a rough estimate to be made of the quantity of the various elements present; for this is usually a more important function of a good qualitative analysis than the mere determination of their presence or absence. To this end tests of excessive delicacy, like certain color reactions, will be avoided, and each element will be obtained in the solid form as a precipitate or residue, as far as possible.

Especial attention will also be devoted to the chemical reactions involved in the process and to the explanations of them furnished by

[1] Copyright, 1906, by ARTHUR A. NOYES.

the Mass-Action Law and Ionic Theory. Since the first systematic application of modern theories to analytical chemistry was made by Ostwald, many physico-chemical researches have been published which make it possible to give such explanations with certainty in a greater number of cases. References to the more important articles relating to the chemistry of the processes and to their theoretical interpretation will be given.

The elements and element-groups included in this system of analysis are primarily those which, with remarkable unanimity, are treated of in the ordinary schemes of qualitative analysis; but we have also introduced the more important of the so-called rare elements, in so far as this has seemed practicable without seriously complicating or modifying the process best adapted to the more common elements. An independent "System of Qualitative Analysis Including Nearly All the Metallic Elements" is also being worked out in this laboratory; and parts of it have already been published under this title in this QUARTERLY. The latter scheme differs from the one here presented in that the detection of the rare elements forms the essential feature, instead of a merely incidental one.

The results will be presented in the form that seems best adapted to the purposes of the analyst. The "System of Analysis" is for convenience in publication primarily divided into a series of parts, each of which treats of one of the large divisions of the subject. Under each part is first presented a "General Discussion," in which are given the reasons for the adoption of the process employed. This is followed by a "Tabular Outline," which gives a survey of the important steps and the chemical reactions involved in the process of analysis. Then comes the chapter entitled, "Procedures and Notes," in which the details of the process are presented and discussed. Next are given the "Test Analyses," which were made with known mixtures in order to test the efficiency of the process. Finally are presented "Confirmatory Experiments and References," which serve to substantiate the statements made in the notes and to justify the details of the procedures.

In the procedures the operations are described in much detail; it is, however, assumed that the analyst is familiar with the manipulative processes of exact qualitative analysis and with the ordinary precautions for assuring completeness of precipitation, washing, etc. In the notes are explained the purposes of the operations and the specific chemical

reactions involved from the point of view of the Mass-Action Law and the Ionic Theory, with the general principles of which the reader is assumed to be acquainted. The directions are almost always given in the form applicable to the case where all elements that might be present are present, the modifications admissible when certain operations lead to negative results being usually sufficiently evident. The scheme consists of a series of numbered "Procedures," a new one being begun whenever the substance has been resolved into two parts (such as a precipitate and filtrate) which are to be submitted to different operations. Procedures which are devoted to the detection or separation of the rarer elements are preceded by an asterisk, and are further designated by a letter attached to the procedure number: they may be omitted if such elements are not to be tested for. Notes under other procedures, when they relate to such elements, are also distinguished by an asterisk. At the beginning of each procedure the one by which the substance was last treated, and at the end of each procedure those by which the two separated portions of it are next to be treated, are referred to by number.

Most of the experiments described under "Confirmatory Experiments and References" are undoubtedly merely confirmations of previously known chemical facts. The application of these facts to the specific conditions of the procedures it was, however, constantly necessary to test; and it has seemed worth while to make the results a matter of record. The experiments are preceded by a reference to the procedure and note to which they relate.

Of the abbreviations employed only a few need be explained: G. D. is used for General Discussion; P. for Procedure; N. for Note; C. E. for Confirmatory Experiments; T. A. for Test Analyses. A number within parentheses expresses the specific gravity at 15°. When it is directed to add a variable quantity of a reagent (for example, 5–15 ccm.), the amount used should be adjusted to the size of the precipitate or residue.

The metallic elements have been classified in "Groups" on the basis of their behavior toward the general ("group") reagents, and these groups are designated and defined as follows, the rarer elements here considered being indicated by an asterisk: *silver group*, elements precipitated wholly or in part by hydrochloric acid (Ag, Pb, Hg [mercurous], *Tl); *copper group*, elements precipitated by hydrogen sulphide from weakly acid solution whose sulphides remain undissolved

in large quantity by yellow ammonium sulphide (Hg [mercuric], Pb, Bi, Cd, Cu, *Au, *Pt); *tin group*, elements precipitated by hydrogen sulphide from weakly acid solution whose sulphides dissolve readily or in considerable quantity in yellow ammonium sulphide (As, Sb, Sn, *Au, *Pt, *Se, *Te, *Mo); *iron group*, elements not precipitated by hydrogen sulphide from acid solution, but precipitated by ammonium hydroxide and sulphide (Co, Ni, Fe, Mn, Cr, Al, Zn, *Ti, *Zr, *U, *V, *Be); the *alkaline-earth group*, elements not precipitated by any of these reagents, but precipitated by ammonium carbonate (Ba, Sr, Ca); the *alkali group*, elements not precipitated by any of the preceding reagents (Mg, Na, K, *Li).

PART I. PREPARATION OF THE SOLUTION

General Discussion

The attempt has been made to devise a systematic method of preparing the solution of the substance for analysis, which shall be uniform for all substances, which in the case of those ordinarily met with shall be as rapid as possible, and which shall be so complete as to effect the solution of substantially all known substances. Heretofore little attention has been given to the development of such a definite, uniform plan of treatment, it being assumed that the analyst has the experience necessary to enable him to select, on the basis of the known general character of the substance or of a series of preliminary tests in the dry way, the most suitable method to employ for its decomposition. Yet more experience is required for this than for the ordinary group separations; and there seems to be no reason whatever why this important and difficult part of the analytical process should not be treated in the same systematic way as are the separations and tests for the various elements.

The general character of the plan here presented for accomplishing this end will be readily seen from the "Tabular Outline" given below. The only preliminary test required is one for the presence of organic matter and water, which is made by heating the substance in a closed tube; thus are eliminated the time-consuming blowpipe tests usually recommended, the success of which can be assured and the true significance interpreted only after much experience. For substances found to

contain organic matter a special treatment with nitric and sulphuric acids is described by which the organic matter is destroyed. Other substances are treated first with water, and, if this does not cause complete solution, immediately after with fairly strong nitric acid; and any residue still remaining is boiled with hydrochloric acid and *aqua regia*, in order to remove a few substances, such as manganese and lead peroxides, mercuric sulphide, gold, and platinum, which are attacked by these acids, but not by nitric acid.

In the treatment of the residue that may remain unattacked by these acids lies the main difference between our process and that ordinarily recommended in text-books on qualitative analysis; for, as shown in Table II, any such residue is heated with sulphuric and hydrofluoric acids instead of being fused with an alkaline carbonate. By this modification the process of preparing the solution is much simplified in the great majority of cases; for silica is thereby detected and eliminated at the start, and almost all silicates are decomposed, yielding at once either a complete solution, or, if lead, barium, strontium, or much calcium is still present, a residue of their sulphates which can readily be decomposed by boiling with sodium carbonate solution. An even more important advantage of this method, however, is that no foreign metallic elements are introduced; while, when a fusion is made, alkali elements are introduced from the flux, and aluminum, calcium, and silica from the porcelain crucible, which ordinarily must be used, owing to the possible presence of reducible metallic elements, thus making it necessary to employ other special methods for the detection of these elements. Objection may be raised to the use of hydrofluoric acid because of its being an expensive and irritating reagent and because it must be handled in platinum vessels, thus making it hardly practicable for the use of large classes of beginners in the subject. Realizing the force of the last consideration, we have described (as indicated in Table III) the usual method of fusion with an alkaline carbonate as an alternative procedure, which may be used under circumstances which do not permit of the simpler and more satisfactory method with hydrofluoric acid. But in doing so we wish to express the conviction that when the subject of qualitative analysis is studied as a branch of analytical chemistry, and not merely as a means of imparting a certain additional chemical knowledge, it ought to be pursued under the same conditions with respect to accuracy of manipulation and availability of facilities as is customary in courses upon quantitative analysis. For

the inability to make a good qualitative analysis is a common source of error in quantitative analytical results; and lack of thoroughness in the instruction in qualitative analysis often develops careless and inaccurate habits of work. We have therefore aimed to develop the scheme of analysis best adapted to the purposes of the analyst, and have not hesitated to avail ourselves of the special methods and reagents commonly used only in quantitative work when a more reliable or simpler process could thereby be developed.

Only few substances, especially a few silicates and native oxides, fail to be dissolved by the treatment with sulphuric and hydrofluoric acids; and it is very rare that any further operations are necessary. But to provide for these special cases it is directed to fuse any residue with alkaline carbonate and nitrate, which can now safely be done in a platinum crucible; and, finally, to fuse any residue still remaining (which is likely to consist only of aluminum, tin, or titanium oxide) with potassium hydroxide.

Tabular Outline

In the "Tabular Outlines" the enclosure of a symbol in brackets shows that the element may divide itself between the residue and solution in the operation immediately preceding. The symbols of the anhydrous substances are given, without reference to the actual state of their hydration in the residue or precipitate.

TABLE I

Determine by preliminary tests whether the substance contains organic matter (P. 1); and if not, whether it dissolves completely in water and forms an acid or neutral solution (P. 3).

<table>
<tr>
<td rowspan="3">SUBSTANCES CONTAINING ORGANIC MATTER.
Heat with H_2SO_4 and HNO_3 to destroy organic matter, evaporate off HNO_3, add water (P. 2).</td>
<td rowspan="3">SUBSTANCES SOLUBLE IN WATER FORMING A NEUTRAL OR ACID SOLUTION.
Dissolve in water, add HCl (P. 11).</td>
<td colspan="3">OTHER SUBSTANCES.
Heat with HNO_3, evaporate, dry, add dilute HNO_3 (P. 3).</td>
</tr>
<tr>
<td rowspan="2">Solution:
Add HCl (P. 3).</td>
<td colspan="2" rowspan="2">Residue: A. From alloys: Sb_2O_5, SnO_2, [P_2O_5], [As_2O_5], SiO_2, [TiO_2], WO_3, C, Au, Pt, Ir, etc.; some iron alloys.
B. From other substances: oxides under A above and substances under B in Table II; also MnO_2, PbO_2, and HgS.
Heat with HCl and HCl + HNO_3, evaporate, dry, add dilute HCl (P. 4).</td>
</tr>
<tr>
<td rowspan="2">Residue.
See Table II or III below.</td>
<td rowspan="2">Solution:
Add HCl (P. 2).</td>
<td rowspan="2">Precipitate: AgCl, HgCl, [$PbCl_2$], [TlCl] (P. 12).</td>
<td rowspan="2">Filtrate: All elements except Ag. Pass in H_2S (P. 21).</td>
</tr>
<tr>
<td>Precipitate: AgCl, [$PbCl_2$], [TlCl] (P. 12).</td>
<td>Filtrate: Evaporate; add HCl (P. 4).</td>
<td>Solution: All elements except Ag. Pass in H_2S (P. 21).</td>
<td>Residue. See Table II or III below.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Precipitate: AgCl. Confirm by P. 15.</td>
<td>Filtrate: All elements except Ag, Cr, Pb, Ba, Sr. Pass in H_2S (P. 21).</td>
<td></td>
<td></td>
<td></td>
</tr>
</table>

TABLE II

Residue Undissolved by Acids from Table I

A. From alloys: [SnO_2], SiO_2, TiO_2, WO_3. (C, Ir, etc., some Fe alloys.)[1]

B. From nonmetallic substances: oxides under **A**; also AgCl, CaF_2, MoS_2, many silicates, the sulphates of Pb, Ba, Sr, native Al_2O_3, $FeO.Cr_2O_3$.

C. From substances containing organic matter: substances under **B** (except CaF_2): also Sb_2O_5, $BiOSO_4$, $Cr_2(SO_4)_3$, $CaSO_4$.

Heat with H_2SO_4 and HF, evaporate to expel HF, dilute, boil (P. 5).

Gas: SiF_4. Presence of Silicon.

Solution: All elements except Pb, Ba, Sr. *Pass in H_2S (P. 21).*

Residue: Pb, Ba, Sr, [Ca], [Bi], [Cr] as sulphates; Sb_2O_5, WO_3; native SnO_2, Al_2O_3, TiO_2, $FeO.Cr_2O_3$; some silicates. *Boil with Na_2CO_3 solution (P. 6).*

Solution: Na_2WO_4. *Test for tungsten (*P. 6a).*

Residue: Pb, Bi, [Ba], Sr, Ca as carbonate; [$BaSO_4$], other substances except WO_3 as above. *Heat with HCl (P. 6).*

Solution: Pb, Bi, Sb, Cr, [Ba], Sr, Ca as chlorides. *Pass in H_2S (P. 21).*

Residue: [$Cr_2(SO_4)_3$], [$BaSO_4$], MoS_2, native oxides and silicates as above. *Fuse with Na_2CO_3 and KNO_3, add HCl, evaporate, add dilute HCl (P. 7).*

Solution: *Test for all elements except alkalies (P. 21).*

Residue: SiO_2; native SnO_2, TiO_2, Al_2O_3. *Remove SiO_2 with HF; fuse residue with KOH (P. 7, N. 3).*

[1] A *metallic* residue obtained from an alloy is not treated as described in the table, but is best fused with Na_2O_2 (P. 4, N. 2).

TABLE III

(Alternative Process)

RESIDUE UNDISSOLVED BY ACIDS FROM TABLE I

Composition: See Heading of Table II

Fuse with Na_2CO_3 and K_2CO_3 in a porcelain crucible, adding KNO_3 if necessary: add water, filter (P. 8).

Solution: Sodium and potassium silicate, stannate, antimonate, arsenate, aluminate, chromate, manganate, tungstate, molybdate, sulphate, and carbonate. *Acidify, evaporate, dry, add dilute HCl (P. 8).*

Residue: Almost any metallic element as metal, oxide, or carbonate. *Add HNO_3 (P. 8).*

Solution: Sn, Sb, As, Mo, Al, Cr, as chlorides. *Pass in H_2S (P. 21).*

Residue: SiO_2, WO_3. *Reject or treat by P. 5 and *6a.*

Solution: Almost any element as nitrate. *Add HCl (P. 8).*

Filtrate: *Evaporate, add HCl, test for all elements except alkalies (P. 21).*

Precipitate: AgCl, $[PbCl_2]$ (*P. 12*).

Residue: Native SnO_2, TiO_2, Al_2O_3. *Fuse with KOH, add water and HCl (P. 7, N. 3), test solution for Sn, Al, Ti.*

Procedures and Notes

Procedure 1. — If the substance is a solid, note its color, odor, and texture; examine it with a lens to determine whether it appears to be heterogeneous, and, if so, note the appearance of its constituents. Note especially whether it is an alloy or a nonmetallic substance. If the substance is an alloy, pass to P. 3. If the substance is not an alloy, to determine whether organic matter or water is present in it, heat gently at first, then strongly, about 0.1 gram of the finely powdered substance in a hard glass tube (of about 0.6 cm. bore and 8 cm. length) closed at one end. Note whether the substance blackens, whether a tarry or aqueous deposit forms on the cold part of the tube, and whether a burnt odor is emitted. If organic matter is thus proved to be absent, pass to P. 3; if proved to be present, pass to P. 2.

If the substance is a solution in water or other volatile liquid, note its odor, test it with litmus paper, and evaporate just to dryness enough to yield a residue of about 1 gram. Test a small quantity of this residue as described in the preceding paragraph. Treat the remainder by P. 3 if organic matter is found to be absent; otherwise, by P. 2.

Notes. — 1. When a complete analysis in the wet way is to be made, it is usually not worth while to make a more extended preliminary examination in the dry way. The closed-tube test is, however, essential, in order to show whether organic matter or water is present; and incidentally it often furnishes other valuable information.

2. Certain kinds of organic matter, especially sugars and hydroxy-acids such as tartaric, citric, and lactic acids, prevent the precipitation of the hydroxides of aluminum and chromium in the subsequent analysis, and must therefore be detected and removed. Moreover, a large quantity of organic matter of any kind interferes with the execution of the analysis; for example, with the operations of solution, filtration, and evaporation. Alloys do not contain organic matter or water; and therefore the closed tube test need not be applied to them.

3. The closed tube test is a more satisfactory method of detecting organic matter than heating in an open vessel. Blackening, unless accompanied by a burnt odor, or by the formation of a tarry deposit, is not due to organic matter. Copper, cobalt, and nickel salts may cause it, owing to the formation of the black oxides on heating.

4. It is usually desirable to determine whether water is a constituent of the substance, and, if so, whether it is present in large or small pro-

portion. This can be done with a fair degree of delicacy by the closed tube test, provided care be taken to keep the upper part of the tube cool during the first of the heating. Water may be present as so-called water of constitution, as in FeO_3H_3 or Na_2HPO_4; as water of crystallization, as in $MgSO_4.7H_2O$; as enclosed water, as in some hydrated silicates like the zeolites or as mother liquor within crystals; and as hygroscopic moisture on the surface. Water of constitution may be expelled only at a fairly high temperature, while in the other forms it is seldom retained above 200°.

5. The closed tube test may also furnish evidence of the presence of certain metallic and nonmetallic elements when they are present in considerable quantity. Thus all ammonium salts and mercury compounds are volatilized much below a red heat: the former give on the upper part of the tube a white sublimate; the chlorides of mercury also give a white sublimate; while most other mercury compounds give a gray one, consisting of minute globules of mercury, made visible by a lens or by rubbing with a wire. Uncombined As, As_2O_3, and As_2S_3 are also readily volatilized, forming black, white, and yellow sublimates, respectively. Of the acid-forming elements or groups, free sulphur or a persulphide is shown by a sublimate of reddish brown drops, changing to a yellow solid on cooling, and accompanied by odor of SO_2; a moist sulphide, by the odor of H_2S; a nitrate or nitrite, by brown vapors of NO_2; free iodine or a decomposable iodide, by a black sublimate of I_2 and by its violet vapor; a sulphite, by the odor of SO_2; a peroxide, chlorate, or nitrate, by evolution of oxygen, recognized by its inflaming a glowing wood-splinter held in the tube; and a carbonate or oxalate, by the evolution of CO_2, recognized by its causing turbidity in a drop of $Ba(OH)_2$ solution.

6. If the substance to be analyzed is a liquid, it is desirable to determine first how much, if any, solid substance is present in it; for enough must be taken for analysis to enable small quantities of the metallic elements to be detected. Moreover, if it is dissolved in a volatile organic solvent the latter is removed by evaporation.

Procedure 2. — If the closed tube test (P. 1) has shown the presence of organic matter, powder, or cut into small pieces, 1 to 5 grams of the substance (according to the quantity of organic matter present) Add to it in a casserole about 5 ccm. H_2SO_4 (1.84); warm gently until the substance is well charred; cool; add slowly, with constant stirring, under a hood, HNO_3 (1.42), until violent reaction ceases; digest for a few minutes on a steam bath, and then heat over a flame, keeping the dish moving, until the substance is thoroughly charred. Cool, again add HNO_3 as before, and heat until thick fumes of H_2SO_4

are evolved; cool somewhat, and add a little HNO_3. Repeat this process till the H_2SO_4 becomes light-colored and remains so when heated strongly.

Evaporate the remaining H_2SO_4 under a hood to about 1.5 ccm. Cool and add carefully about 10 ccm. water. If there is a residue, cover the casserole and boil the mixture (to extract slowly dissolving sulphates); cool, filter, and wash, first with H_2SO_4 (1.20) and then with a little water, rejecting the washings. (Residue, P. 5.) To the solution add a drop of HCl (1.12). (If a precipitate forms, add more HCl, but only as long as a precipitate continues to separate; filter, wash the precipitate, and test it for silver by P. 15.) Dilute the solution to a volume of 40 ccm. (Solution, P. 21.)

Notes. — 1. This method of destroying organic matter is of very general application, being effective even when such stable substances as paraffin are present. Organic matter can also be destroyed by ignition, but this has the disadvantages of volatilizing certain elements, especially mercury and arsenic, and of making some substances very difficultly soluble. When the organic matter consists only of oil, as is the case with an oil paint, it may be better to extract it with ether, especially when it is desired to determine the proximate constituents of the substance.

2. The residue contains: any substances originally present that have not been attacked by HNO_3 or H_2SO_4, especially silicates; all the lead, strontium, and barium that may have been present in any form, since the sulphates of these elements are insoluble in dilute H_2SO_4; all the silica, since silicic acid is dehydrated and made insoluble by heating with H_2SO_4; some of the calcium, bismuth, antimony, and tin, when these elements are present in moderate quantity, since their sulphates (or oxides) are not readily soluble in dilute H_2SO_4; and substantially all of the chromium, since its sulphate is converted into the insoluble anhydrous form.

3. After the organic matter is destroyed, the solution is evaporated to about 1.5 ccm. and the solution is finally diluted to 40 ccm., in order that the concentration of the acid may be right for the subsequent H_2S precipitation.

Procedure 3. — If organic matter is absent (P. 1), reduce the substance to a finely divided form (as described in N. 1); weigh out into a casserole about 1 gram if it is a nonmetallic substance, or about 0.5 gram if it is an alloy.

In case the substance is not an alloy, add to it 10–30 ccm. water,

heat to boiling, and test the solution with litmus paper. If the substance has dissolved completely and the solution is neutral or acid, treat the solution by P. 11. If there is a residue or if the solution is alkaline, add carefully without filtering 5–10 ccm. HNO_3 (1.42), and evaporate just to dryness.

In case the substance is an alloy, pour over it 10 ccm. HNO_3 (1.20), cover the dish with a watch glass, heat the mixture on a steam bath as long as any action continues, adding a little HNO_3 (1.42) if action is renewed thereby, or a little water if crystalline salts have separated, and then evaporate just to dryness.

Heat the residue obtained in either case at 120–130° until it is perfectly dry, by keeping the casserole in motion over a flame, or, better, by heating it in a hot closet at that temperature for at least half an hour. Loosen the dehydrated residue from the dish and rub it to a fine powder with a pestle; add to it 5–10 ccm. HNO_3 (1.20), cover the dish, and heat on a steam bath for 10 minutes. Dilute with 20 ccm. water, heat to boiling, filter, and wash the residue. (Residue, P. 4.) To the solution add 5 ccm. HCl (1.20) to precipitate the silver group, filter, and wash the precipitate with a little cold water, adding the washings to the filtrate. (Precipitate, P. 12; filtrate, P. 4, second paragraph.)

Notes. — 1. In order that in the following procedures difficultly soluble substances may be dissolved, the substance must be reduced to a very fine powder. This is usually best accomplished by grinding the substance, in small quantities at a time, in a mortar. With hard substances, and in general with minerals, an agate mortar should be used. Most alloys cannot be powdered in this way; these may be converted into a form that offers a large surface by hammering in a steel mortar, filing with a fine steel file, shaving with a knife, or converting into turnings with a lathe.

2. The quantity of the substance taken for analysis should always be approximately known; for a good qualitative analysis should show, not merely the presence or absence of the various elements in the substance, but should enable their relative quantities to be estimated. Since 1–2 mgm. of almost any element can be detected by this system of analysis, the presence of 0.1–0.2% of an element will be detected when a gram of substance is taken, and this degree of delicacy is ordinarily sufficient. If much more than this quantity is taken, the precipitates may be so large that much time is consumed in filtering and washing them. For this reason it is best to use only about half a gram of an

alloy, since, owing to the absence of acid radicals, the same quantity of metallic elements is contained in a less amount of substance.

3. When the substance dissolves only partly in water, it is not worth while to filter off the residue and analyze it and the solution separately, unless special information in regard to the soluble constituents is desired. If, therefore, it is known to be partly insoluble in water, it is best treated at once with HNO_3, as is directed in the case of an alloy. If, however, it is completely soluble in water, the addition of HNO_3 is avoided, since it would have to be removed before the subsequent precipitation with H_2S.

4. If the aqueous solution has an alkaline reaction, the addition of an acid may cause precipitation of any substance held in solution by an alkaline solvent; for example, sulphur or sulphides of the tin group from an alkaline sulphide solution; silver chloride or cyanide from a potassium cyanide solution; silicic acid from sodium silicate solution; or metallic hydroxides from solutions in alkalies. An alkaline solution should, therefore, not be treated directly with HCl by P. 11, for the precipitate formed might contain other substances than chlorides of the silver group.

5. An acid reaction of the aqueous solution is due to hydrogen ions, which may arise from free acid, from an acid salt of a strong acid, or (by hydrolysis) from a neutral salt of a strong acid and a weak base. An alkaline reaction is due to hydroxide ions, which may arise from a soluble hydroxide, or (by hydrolysis) from a carbonate, sulphide, phosphate, borate, cyanide or a salt of some other weak acid. It is to be noted that the terms "acid salt" and "neutral salt" refer only to the extent of the replacement of the hydrogen of the acid by the metallic element, and do not show the reaction towards litmus or other indicators. This reaction depends on the presence of a sufficient concentration of hydrogen or hydroxide ions to affect the indicator employed. Thus the neutral salts Na_2CO_3, Na_2S, etc., and even the acid salts $NaHCO_3$, Na_2HPO_4, react alkaline with litmus; while some other neutral salts, such as $Al(NO_3)_3$, react acid.

6. When an acid is added to a nonmetallic substance or its aqueous solution, the evolution of any gas and its odor should be noted, since this indicates the nature of the acid radical present. Thus carbonates evolve CO_2; sulphides, H_2S; sulphites, SO_2; and cyanides, HCN. On boiling the HNO_3 solution, the presence of sulphides is further indicated by the separation of sulphur as a spongy or pasty mass, which floats on the surface and may be removed by means of a spatula or rod; and the presence of iodides is shown by the liberation of free iodine, which may separate as a black precipitate, which imparts a brown color to the solution, and which gives rise to violet vapors above it.

7. In dissolving nonmetallic substances either HNO_3 or HCl may be first used, each having advantages and disadvantages of its own. HNO_3 dissolves, owing to its oxidizing power, many alloys and sulphides not attacked by HCl, but fails to dissolve certain oxides, especially MnO_2, Sb_2O_5, and hydrated SnO_2, which dissolve in HCl. HCl may cause the precipitation of chlorides of the silver group; while strong HNO_3 on heating oxidizes sulphides partially to sulphates, and may cause the precipitation of lead, barium, strontium, and calcium sulphates; thus in either case making it sometimes impossible to determine whether complete decomposition has resulted. HNO_3 oxidizes mercurous, arsenous, antimonous, stannous, and ferrous compounds to the higher state of oxidation: consequently almost all the antimony and tin will usually be found in the residue insoluble in dilute HNO_3 after evaporation, all the mercury will be in the H_2S precipitate, and sulphur will always be precipitated by H_2S when iron is present. When HCl is used as a solvent, mercury, selenium, and arsenic in the arsenous form would be wholly or partly lost, owing to the volatility of their chlorides, in the subsequent evaporation, which is necessary in order to remove silica. For this last reason, and for the reason that the procedure is a more general one in that it provides for the solution of alloys and of a larger proportion of nonmetallic substances and for the isolation of the silver group, the use of HNO_3 is here recommended. In special cases it is advantageous to use dilute HCl instead of HNO_3, especially when the substance dissolves completely in HCl and it is not necessary to evaporate the solution to remove silica.

8. When a silicate is decomposed by acid, silicic acid may separate as a gelatinous precipitate, but even then a part of it always remains in solution, mainly as a colloid. When thoroughly dried at 100–130°, it is partially dehydrated and becomes entirely insoluble. The HNO_3 acid solution is therefore evaporated to dryness and the residue is heated at 120–130°, in order to remove the silica at this point; for, if it were not removed, it would appear as a gelatinous precipitate at some later stage of the analysis; thus, if it did not separate earlier, it would be precipitated by NH_4OH together with the iron group and might then be mistaken for aluminum hydroxide. In the case of nonmetallic substances which cannot contain silica, the evaporation and heating at 120–130° may be omitted.

9. With reference to the treatment of alloys with HNO_3 the following facts should be borne in mind. All the more common elements are dissolved by strong HNO_3 except antimony, tin, and silicon. These are oxidized to antimonic acid ($Sb_2O_5.nH_2O$), metastannic acid (nH_2SnO_3), and silicic acid, which separate at once as white amorphous precipitates

except when only small amounts of these elements are present. Certain nitrates, especially that of lead, may separate in crystalline form from the strong HNO_3, but these dissolve upon adding water and heating to boiling. *Of the more important rarer elements, titanium and tungsten, like antimony and tin, separate in the form of insoluble hydroxides; in the case of tungsten, tungstic acid (H_2WO_4) separates as a dense precipitate of a yellow color.

10. In the case of an alloy the evaporation to dryness and heating at 120–130° serve to partially dehydrate the hydroxides of silicon, tin, antimony, titanium, and tungsten, whereby they are rendered nearly insoluble in HNO_3, and thus make possible a conclusion in regard to their presence or absence. If after having thoroughly dried the mixture at this temperature there is no residue insoluble in the HNO_3 (1.20), it shows the absence of silicon, tin, and tungsten in quantity as large as 1 mgm., and that of antimony and titanium in quantity as large as 2 or 3 mgm. The fact must not be overlooked, however, that in the dehydrated form even a very small residue or slight turbidity may correspond to an appreciable quantity of one of these elements. Therefore, if no residue can be seen, rub the sides of the dish gently with the rubber-covered end of a glass rod, pour into a small flask, allow the liquid to stand 2 or 3 minutes, and note whether there is any residue whatever. The knowledge that tin is absent is helpful, since the subsequent procedures for the detection of this element may be omitted. The subsequent procedures for antimony may, in the absence of a residue, also be omitted, provided quantities as small as 3 mgm. are not to be tested for. In addition to the hydroxides named above the residue may also contain a considerable quantity of stannic phosphate or arsenate when tin and phosphorus or arsenic are simultaneously present, or of bismuth hydroxide when both antimony and bismuth are present; also small quantities of various other elements enclosed in a residue consisting of those already mentioned.

11. The hydroxides referred to in the last two notes usually separate also in the treatment of nonmetallic substances with HNO_3 when the corresponding elements are present; but the nonexistence of a residue must not, except in the case of silicon, be regarded as conclusive evidence of their absence in such substances. For acid radicals may be present which by combination with the hydroxides cause them to remain in solution; thus the presence of chloride or sulphate might cause a considerable quantity of tin, antimony, or titanium to dissolve, while that of phosphate might lead to the solution of even a large quantity of tungsten.

12. A black or metallic residue insoluble in HNO_3, obtained in the case of an alloy, may contain carbon or carbides, certain alloys of iron, such as ferrochrome or ferrosilicon, gold, or any of the platinum metals. If there is no such residue, it shows the absence of gold and platinum.

13. If the substance is nonmetallic, the residue insoluble in HNO_3 probably consists of one or more of the following substances: the partially dehydrated hydroxides of tin, antimony, silicon, titanium, and tungsten; the native or ignited oxides of the same elements, of aluminum, and of chromium; anhydrous chromic salts; the peroxides of manganese and lead; the sulphates of barium, strontium, and lead; the sulphides of mercury and molybdenum; silica; the silicates and fluosilicates of many elements; fluoride of calcium; the halides of silver and lead; the phosphates of tin and of rare earths; ferrocyanide of iron; sulphur; carbon; silicon carbide.

14. In regard to the precipitation of the silver group by HCl, see notes on P. 11.

Procedure 4. — To the residue insoluble in HNO_3 (P. 3) in a casserole add gradually 5–10 ccm. HCl (1.20), and heat as long as action continues, adding more acid if necessary. If the substance does not dissolve completely in HCl, add to the mixture without filtering one-third its volume of HNO_3 (1.42), and heat gently as long as action continues, adding more of the acids if necessary.

To this solution in HCl alone, or in HCl and HNO_3, without filtering off any residue, add the filtrate obtained in P. 3, and evaporate the mixture nearly to dryness. In order to expel the HNO_3, moisten the residue with 2–5 ccm. HCl (1.20), and evaporate to dryness. Thoroughly dry the residue by heating it at 120–130° in a hot closet or by keeping it in motion over a small flame. Add to the residue 4 ccm. HCl (1.12), measured in a small graduate, and about 20 ccm. water; boil gently for a few minutes if there is a residue; filter, and wash the residue thoroughly with boiling water. Pour the filtrate into a graduate and add enough water to make its volume 40 ccm. (Residue, if nonmetallic, P. 5, if metallic, P. 4, N. 2; solution, P. 21.)

Notes. — 1. Of the substances that may be present in the residue undissolved by HNO_3 (see P. 3, N. 12 and 13) the peroxides of manganese and lead are reduced and dissolved by concentrated HCl; antimonic acid, stannic phosphate, and much metastannic acid are also dissolved by it. Upon the addition of HNO_3, whereby the strongly oxidizing mixture known as *aqua regia* is produced, gold, platinum, and mercuric sulphide are entirely dissolved; and silver compounds, such as AgBr, AgI, and AgCN, are converted into AgCl. The chloride of silver and the sulphates of strontium and lead dissolve in large quantity in the concentrated acids, but only in much smaller quantity in the small amount

of dilute HCl added after the evaporation. Some of the other substances that may be in the residue, especially the oxides and certain silicates, are slowly attacked by the strong acids, but the solvent action is not rapid enough to make this a practicable method.

2. If the original substance was an alloy, a residue after the treatment with HCl and HNO_3 probably consists, if nonmetallic, only of metastannic, silicic, titanic, or tungstic acid; if black or metallic, of carbon, a platinum metal, or an alloy of iron with chromium, silicon, etc. If nonmetallic, it is treated with H_2SO_4 and HF by the regular procedure, in order to test for and remove silica and to dissolve metastannic and titanic acids. If metallic, such a treatment would not effect solution; the residue is then best fused with Na_2O_2 in a nickel crucible, the mass treated with water and HCl, and the solution analyzed as usual, except that nickel cannot be tested for. For a description of this process and the results attained by it, see A. A. Noyes, "System of Qualitative Analysis Including Nearly All the Metallic Elements," Part I, Procedure 13, published in this QUARTERLY, 16, p. 113 (1903).

3. The solution is evaporated to render insoluble silicic acid which may have come from the decomposition of silicates, and to remove the large quantity of acid which would otherwise interfere with the H_2S precipitation. The evaporation with HCl serves, moreover, to remove HNO_3, which, if present in large quantity, would destroy the H_2S with liberation of sulphur. Since the success of the separation by H_2S of the copper and tin groups from the iron group requires a proper concentration of acid in the solution, a measured quantity of HCl is added and the solution is diluted to a definite volume.

4. If the original substance was an alloy and a large, nonmetallic residue remains after treatment with HNO_3 (P. 3), it is sometimes advantageous to analyze the residue separately by the following procedure, by which a large quantity of metastannic acid is more readily dissolved: Add to the residue in a casserole 3–4 ccm. concentrated H_2SO_4, and heat under the hood until the acid has evaporated to a volume of about 2 ccm. Cool, add an equal volume of water, cool again, add 5 ccm. HCl (1.12) to dissolve antimonic oxide, and heat to boiling. Cool completely, filter if there is a residue (which may consist of silicic or tungstic acid), and add the acid solution drop by drop, with constant shaking, to a mixture of 10 ccm. ammonium monosulphide, 1 ccm. ammonium polysulphide, and 10 ccm. NH_4OH (0.90) in a flask. Cover the flask and digest for a few minutes on a steam bath. Filter out the precipitate, which may consist of titanium hydroxide or small quantities of sulphides of the copper and iron groups. Dilute the filtrate, and make it slightly acid with HCl. Shake to coagulate the precipitate,

filter, and wash with hot water. Analyze the precipitate for the tin group by P. 42; reject the filtrate or test it for phosphate with molybdic acid.

Procedure 5.[1] — Transfer to a platinum crucible the residue after treatment with acids (P. 2 or P. 4), add 2 ccm. H_2SO_4 (1.84) from a graduate, heat with a moving flame until white fumes are given off, and cool completely. To test for silica, add carefully (see N. 1), from the loop of a platinum wire, pure 40% HF drop by drop until 5–6 drops have been added, and warm the mixture over a steam bath. (Formation of gas bubbles, presence of SILICA.)

Then add about 5 ccm. more pure 40% HF, cover the crucible with a platinum cover, digest on a steam bath for about 15 minutes unless the residue dissolves more quickly; remove the cover and evaporate carefully until white fumes of H_2SO_4 are given off, heating the sides of the crucible with a moving flame, or, better, with a ring-burner to avoid spattering. [Unless it is known from the presence of solid substance at this point or from previous observations that the residue treated with H_2SO_4 and HF contained other constituents than silica, determine this by evaporating off the H_2SO_4 under a hood, taking care not to ignite the residue. If a significant residue remains, add from a graduate 1.5 ccm. H_2SO_4 (1.84), and heat until the residue is redissolved, not allowing the acid to evaporate.] Cool, pour the contents of the crucible into 10 ccm. water, and rinse out the contents with a little water. Boil to dissolve slowly dissolving sulphates; cool, shake, filter, and wash the residue, first with H_2SO_4 (1.20) and then with a little water, rejecting the washings. (Residue, P. 6.) To the filtrate add HCl drop by drop only as long as a precipitate forms; filter, wash the precipitate, and test it for silver by P. 15. Dilute the filtrate to a volume of 40 ccm., treat it with H_2S by P. 21, subsequently testing for all the metallic elements except lead, barium, and strontium.

Notes. — 1. Great care must be taken not to breathe the fumes of HF nor to get it on the hands; for it is very irritating and produces dangerous burns.

2. The test for silica or silicate depends on the formation of SiF_4 gas, which is insoluble in strong H_2SO_4, but dissolves in water in the presence of HF with formation of fluosilicic acid, H_2SiF_6. With free silica the evolution of gas takes place in the cold; but with slowly decompos-

[1] For an alternative procedure, see N. 7 below and P. 8.

ing silicates, such as feldspar, the test is obtained only upon warming. A few silicates are not acted upon by HF and H_2SO_4, and, of course, do not show the test for silica at this point. The test is delicate enough to enable 1 mgm. of silica, whether free or in a decomposable silicate, to be detected. Moreover, after the substance has been treated with acids as in P. 4 and warmed with H_2SO_4, an evolution of gas with HF is not produced with the compounds of any element other than silicon (not even with those of titanium, niobium, and tantalum, which form somewhat volatile fluorides). It should be borne in mind that a small quantity of silica will be introduced if ordinary filters (which have not been washed with HF) have been employed and have been destroyed by acids or by ignition, or if a strongly alkaline solution has been boiled in glass vessels, or if a substance has been fused with sodium carbonate in a porcelain crucible.

3. Since glass and porcelain consist of silicates which are readily attacked by HF, this acid must not be allowed to come into contact with these materials. In handling cold HF solutions, vessels and funnels of celluloid or paraffin or of glass coated with paraffin may be used; but platinum vessels must be employed when the solutions are to be heated. Care must be taken not to introduce into a platinum vessel any solution containing chlorine or bromine or any acid mixture containing nitrates and chlorides by which chlorine would be evolved. Platinum is so slowly attacked by hot concentrated H_2SO_4 that even when 2–3 ccm. of the acid are rapidly evaporated in a crucible less than half a milligram passes into solution; but, if the acid is boiled for 10–15 minutes in a covered vessel, 2 or 3 mgm. may be dissolved, and would be precipitated subsequently by H_2S.

4. The digestion with HF decomposes most silicates and dissolves silica (and much titanium oxide). The subsequent evaporation with H_2SO_4 expels the excess of HF and decomposes the fluorides produced, as well as some other substances that may have been left undissolved by the HNO_3 and HCl. The H_2SO_4 solution is diluted with a small quantity of water so as to cause the complete precipitation of $BaSO_4$, $SrSO_4$, and $PbSO_4$. These sulphates are moderately soluble in strong H_2SO_4 and may not appear till after dilution. The addition of much water is avoided, since $SrSO_4$ and $PbSO_4$ are somewhat soluble in water; and the residue is washed with dilute H_2SO_4 for the same reason. The solution is boiled so as to dissolve anhydrous sulphates, such as those of aluminum and iron.

5. The residue insoluble in dilute H_2SO_4 contains as sulphates all the barium, strontium, and lead, and all of the calcium in excess of 5–10 mgm., left undissolved by HNO_3 and HCl; more or less of the

chromium (according as the H_2SO_4 has been more or less strongly heated) as a pink anhydrous sulphate; and part of the bismuth as basic sulphate and antimony as antimonic hydroxide, when much of these elements were left undissolved by the previous treatments with acids. The residue may also contain still undecomposed substances, especially the following: silver chloride; corundum, Al_2O_3; chromite, $FeCr_2O_4$; cassiterite, SnO_2; rutile, TiO_2; tungstic oxide, WO_3; molybdenum sulphide, MoS_2; some anhydrous silicates and fluosilicates, such as cyanite or andalusite (Al_2SiO_5) and tourmaline; graphite and carbides.

6. If the presence of silver is shown by the addition of HCl, the residue insoluble in dilute H_2SO_4 is likely to still contain AgCl, which is only slowly decomposed by hot concentrated H_2SO_4. In order to dissolve this, add to the residue in a small casserole 3–5 ccm. concentrated H_2SO_4, heat until white fumes are given off, cover the dish with a large watch glass, and boil gently for 5–10 minutes. Cool, and treat as described in the last paragraph of the above procedure. If AgCl is not completely removed in this way, its presence will be shown by a blackening of the residue upon boiling with Na_2CO_3 solution in P. 6; in such a case it must be removed by further treatment with H_2SO_4 before a fusion with Na_2CO_3 is made in a platinum crucible (P. 7). By this treatment with boiling H_2SO_4, Al_2O_3 and TiO_2, if present in the residue, are also dissolved in large quantity.

7. If the use of a platinum crucible or of hydrofluoric acid is impracticable, the residue insoluble in HCl and HNO_3 may be fused in a porcelain crucible with a mixture of Na_2CO_3 and K_2CO_3, as described in P. 8, instead of being treated by P. 5–7. This is, however, a far less satisfactory method of analysis for the following reasons. Compounds of the alkali elements are used as a flux, and aluminum, calcium, and silica are introduced from the porcelain crucible, so that these elements cannot be tested for in the insoluble residue. Moreover, the treatment with HF and H_2SO_4 is almost always a shorter process, since when the residue consists only of silica, as is often the case with minerals, no further treatment is necessary, and since in other cases there is often no residue to be boiled with Na_2CO_3 solution (P. 6) and seldom one to be fused with Na_2CO_3 (P. 7). A fusion in a platinum crucible with alkali-metal carbonate would be less objectionable; but this is not possible unless reducible metallic elements are known to be absent in the residue (see P. 7, N. 1).

Procedure 6. — Transfer the residue insoluble in H_2SO_4 (P. 5) to a casserole, add about 25 ccm.[1] saturated Na_2CO_3 solution, cover

[1] See, however, *P. 6*a*, N. 1, if a small quantity of tungsten is to be tested for.

the casserole, and boil gently for 10 minutes. Filter and wash the residue thoroughly. (Filtrate, reject or test for tungsten by *P. 6*a*.) Heat the residue with 5 ccm. HCl (1.12), measured in a graduate, and 10 ccm. water; filter, wash the residue, and treat it by P. 7. Dilute the solution to 40 ccm., and treat it with H_2S by P. 21, subsequently testing it only for lead, bismuth, antimony, chromium, barium, strontium, and calcium.

Notes. — 1. The boiling with Na_2CO_3 converts into carbonates the sulphates of lead, calcium, strontium, and bismuth completely, and at least 80% of the sulphate of barium, even when large quantities of them are present. A second treatment, which should be applied to the residue if there are indications that barium is present, completely decomposes $BaSO_4$. The carbonates dissolve readily in HCl. Anhydrous chromic sulphate, which is left undissolved by dilute H_2SO_4 (P. 5) as a fine pink or gray powder, is slowly changed by boiling with Na_2CO_3 to a greenish blue hydroxide which dissolves in the HCl, leaving behind the still undecomposed sulphate. Antimonic oxide dissolves only to a small extent (2–4 mgm.) in the Na_2CO_3 solution, but dissolves upon boiling with HCl. Tungstic oxide passes into the Na_2CO_3 solution as sodium tungstate (Na_2WO_4).

2. Any residue insoluble in HCl can therefore consist only of barium and chromic sulphates or of some of the original substance still undecomposed, consisting, probably, of one of the native oxides or silicates mentioned in P. 5, N. 5. Such a residue will seldom be obtained; and if so, it can ordinarily be rendered soluble by fusion with Na_2CO_3 and KNO_3 (or with KOH) as described in P. 7 (or P. 7, N. 2).

3. The residue undissolved by dilute H_2SO_4 after the treatment with HF (P. 5) is first boiled with Na_2CO_3 solution and not at once fused, since it is necessary to remove the reducible metals, lead, bismuth, and antimony, before a platinum crucible can be used for the fusion. Moreover, the boiling with Na_2CO_3 solution makes subsequent fusion unnecessary when the residue consists only of sulphate of lead or of an alkaline-earth element.

* **Procedure 6a.** — Acidify the Na_2CO_3 solution (P. 6) with HNO_3, evaporate almost to dryness, add 1–2 ccm. HNO_3 (1.20); add enough water to dissolve the salt, boil, and cool. (Yellow precipitate, presence of TUNGSTEN.) Filter and wash the precipitate, rejecting the solution. Pour through the filter 2 ccm. NH_4OH (0.96) to dissolve any H_2WO_4,

acidify the filtrate with HCl (1.20), and add a few granules of zinc. (Blue color, presence of TUNGSTEN.)

Notes. — 1. When HNO_3 is added to a tungstate solution a hydrated tungstic acid separates as a white flocculent precipitate, which changes upon boiling to a yellow powder (H_2WO_4). The test is not very delicate in the presence of a large amount of salt: when 25 ccm. Na_2CO_3 solution are used, as is directed in P. 6, even 3 mgm. of tungsten can barely be detected in this way. Therefore, when tungsten is to be tested for, the residue from P. 5 should first be boiled with a small portion (5 ccm.) of Na_2CO_3 solution, and this solution tested for tungsten as described above; under these conditions 1 mgm. can be detected. The test is entirely unsatisfactory if H_2SO_4 or HCl is used, in place of HNO_3, in neutralizing the Na_2CO_3.

2. The blue color obtained upon reduction with zinc, which serves as a confirmatory test for tungsten, is due to a suspended, quickly coagulating precipitate, consisting of a hydrated oxide intermediate between WO_3 and WO_2. Prolonged action of zinc may cause the blue color to disappear, owing to complete reduction to WO_2.

3. At this point will usually be found all the tungsten in the substance in excess of 2 mgm., which amount remains in solution in the H_2SO_4 (P. 5). When, however, phosphate is also present in the substance, tungsten would not remain as H_2WO_4 in P. 3 and 4, but would pass into the acid solution, owing to the formation of a complex phospho-tungstic acid.

Procedure 7. — Transfer the residue insoluble in HCl (P. 6), with the filter if necessary, to a platinum crucible, heat until the residue is dry or until the filter is destroyed, mix the residue with 5–10 grams of anhydrous Na_2CO_3 and 0.1–0.5 gram of solid KNO_3, cover the crucible, and heat over a powerful burner. After some minutes note whether a perfectly fluid fusion has resulted. If not, heat more intensely over a blast lamp for 10 minutes, adding, if necessary, more Na_2CO_3. Cool, place the crucible in a casserole, add carefully HCl (1.12) till the solution remains strongly acid, evaporate to dryness, and heat at 120°–130° to render silica insoluble; add from a graduate 4 ccm. HCl (1.12) and 10–20 ccm. water, boil, and filter. Dilute the filtrate to 40 ccm., and treat it with H_2S by P. 21, subsequently testing it for all metallic elements except the alkalies. Test the residue for silica by P. 5 and remove it if present; if a residue still remains, treat it as described in N. 3.

Notes. — 1. Compounds of the elements of the silver, copper, and tin groups that may be reduced to the metal by heating with an alkaline flux must not be heated in platinum. The same is true of sulphur, sulphides, and in the presence of organic matter of phosphates; for all these elements form easily fusible alloys with the platinum, and thus spoil the crucible. If, however, the substance has been treated by the preceding procedures, none of these substances can be present. Moreover, alkaline hydroxides and strongly oxidizing fluxes (such as peroxides and nitrates) must not be fused in platinum, since they attack it fairly rapidly. Therefore, no more nitrate should be added to the Na_2CO_3 fusion than is necessary.

2. In regard to the decomposition of substances in general by fusion with Na_2CO_3, see P. 8, N. 1. Of the substances that may be present in the residue which has been boiled with Na_2CO_3 solution, the silicates are decomposed by fusion with Na_2CO_3 alone. But in order to render chromium compounds (and molybdenum sulphide) soluble, they must be oxidized; and for that purpose a little KNO_3 is added. The native and ignited oxides of tin, aluminum, and titanium are only slowly acted upon by the flux, and remain insoluble with the silica upon the subsequent treatment with acid. $BaSO_4$, if still present, will also remain with the silica; for, though it is converted into $BaCO_3$ and Na_2SO_4 by the fusion, it is formed again when the mass is treated with acid.

3. Any residue insoluble in dilute HCl probably consists, therefore, only of SiO_2, TiO_2, $BaSO_4$, Al_2O_3, and SnO_2. Such a residue is best treated first by P. 5 and 6, to remove SiO_2 and $BaSO_4$, and any residue still remaining may then be treated as follows: Reduce it to a very fine powder, transfer it to a nickel or silver crucible, dry thoroughly, add 5–10 grams pure solid KOH, and fuse the mixture for 10–20 minutes. Cool, extract with about 30 ccm. water, and filter. Neutralize the solution exactly with HCl (1.12). Treat the residue with about 5 ccm. HCl (1.12), filter out any residue of undecomposed substance, and unite the solution with the neutral aqueous extract. Treat the mixture by the regular procedure beginning with P. 21, testing especially for tin, titanium, and aluminum. The native and ignited oxides of aluminum, stannic tin, and titanium, if finely powdered, dissolve rapidly in fused KOH; and the aqueous extract contains the aluminum as aluminate and most of the tin as stannate. The residue undissolved by water may consist of black nickel oxide from the crucible, stannic hydroxide, potassium titanate, and sometimes other hydroxides accompanying the aluminum or tin oxides. All of these dissolve in HCl.

Procedure 8. — If the use of HF (P. 5) is impracticable, transfer the residue insoluble in acids (P. 2 or 4), with the filter if necessary, to

a porcelain crucible, heat until the residue is dry or until the filter is destroyed, mix the residue, which must be very finely divided, with ten to twenty times its weight of a mixture of anhydrous Na_2CO_3 and K_2CO_3, cover the crucible, heat strongly over a powerful burner or over a blast lamp so that complete fusion takes place, and continue the heating for 10–30 minutes. If dark particles of undecomposed substance can still be seen, add gradually in small portions 0.1–0.5 gram of solid KNO_3, and heat strongly for several minutes. Cool, boil the crucible and its contents with water until the fused mass is disintegrated, filter, and wash the residue thoroughly. Warm the residue with HNO_3 (1.20) until action ceases, and filter out any still undecomposed substance (see N. 2 below.) Mix a small part of the HNO_3 solution with a small part of the Na_2CO_3 solution, making the mixture strongly acid with HNO_3, if it is not already so.

If no precipitate forms, mix the remainder of the acid solution with about half the Na_2CO_3 solution, reserving the rest of the Na_2CO_3 solution for the tests for acid radicals. Add about 5 ccm. HCl (1.12) (or more if the solution is still alkaline), and filter. (Precipitate, test for silver and lead, P. 12.) Evaporate the solution to dryness, moisten the residue with HCl, and again evaporate to decompose nitrates. Heat the residue until it is thoroughly dry at 120–130° in a hot closet or by keeping it in motion over a small flame. Add from a graduate 4 ccm. HCl (1.12) and about 20 ccm. water; heat to boiling, filter, reject the residue, and dilute the filtrate to 40 ccm. (Filtrate, P. 21.)

If a precipitate forms on mixing small portions of the HNO_3 solution and the Na_2CO_3 solution, treat these solutions separately as described in the preceding paragraph, uniting the precipitates formed by the same group reagent in the subsequent analysis.

Notes. — 1. Upon fusion with Na_2CO_3 most compounds undergo metathesis, the acid radical of the compound combining with the sodium, and the metallic element with the carbonate radical. The carbonate formed is, however, sometimes decomposed by heat with production of the oxide or of the metal itself. Acid-forming oxides, such as SiO_2, As_2O_5, and less rapidly Al_2O_3, expel CO_2 from the Na_2CO_3 and form sodium salts. Such reactions are illustrated by the following equations:

$$BaSO_4 + Na_2CO_3 = Na_2SO_4 + BaCO_3.$$
$$Fe_2SiO_5 + Na_2CO_3 = Na_2SiO_3 + Fe_2O_3 + CO_2.$$
$$4AgCl + 2Na_2CO_3 = 4NaCl + 4Ag + 2CO_2 + O_2.$$
$$SiO_2 + Na_2CO_3 = Na_2SiO_3 + CO_2.$$

After the treatment with water, the acid radical of the substance is therefore found with the excess of Na_2CO_3 in the aqueous extract, while the metallic component remains undissolved by the water and passes into the acid solution.

2. Some substances which are not much acted upon by Na_2CO_3 alone are readily attacked when an oxidizing flux like KNO_3 is present. Thus sulphides are converted into sulphates and chromium compounds (such as chromite, $FeO.Cr_2O_3$) into chromates. A few substances, however, such as the oxides of tin, aluminum, and titanium, may be only partially decomposed even by long-continued fusion with the mixed fluxes. An undecomposed residue is best fused with KOH in a nickel or silver crucible and the fusion treated, as described in P. 7, N. 3, first with water and then with HCl.

3. The porcelain crucible is so attacked by the flux that it cannot well be used for a second fusion. Aluminum, calcium, and silica are taken up by the flux, so that these elements, as well as the alkali elements, cannot be tested for later in the analysis. In case all reducible metallic elements and sulphides are known to be absent (see P. 7, N. 1), it is therefore better to make the fusion in a platinum crucible, since then no foreign substances are introduced from the crucible. If platinum is not available, or if it is not known that reducible elements are absent, a pure nickel crucible can be used with advantage in place of the porcelain one. This enables aluminum, calcium, and silica to be tested for; some nickel, but only a few milligrams, will then be found in the acid solution of the fusion. Reducible elements, if present, would alloy with the nickel, but the destruction of a crucible of this cheap material is not of much consequence. Ordinarily a nickel crucible can be used repeatedly.

4. The first and third reactions given in N. 1 are examples of cases where the aqueous and acid solutions must not be mixed, for upon mixing $BaSO_4$ or AgCl would again be formed.

5. Of the metallic elements that may be present, all or a part of the arsenic, antimony, tin, molybdenum, tungsten, aluminum, chromium, and manganese are contained in the Na_2CO_3 solution; and this solution must therefore be analyzed for metallic elements. Since this solution may also contain Na_2SiO_3, the solution after the addition of HCl is evaporated to dryness, and the residue is heated at 120–130°; this treatment partially dehydrates the silicic acid and renders it insoluble in HCl. The residue insoluble in HCl after this treatment usually consists only of silicic acid (or tungstic acid). To prove whether it consists wholly of silica, it may be treated with H_2SO_4 and HF as described in P. 5. * To test for tungsten it may be treated with HCl and zinc as described in * P. 6*a*.

6. The residue left after the extraction with water is treated with HNO_3 rather than with HCl, so as to dissolve reduced metals and to prevent the formation of AgCl and $PbCl_2$ at this point.

Confirmatory Experiments and References

P. 2, N. 1: Destruction of Organic Matter. — 3 grams white flour, 1.5 grams glycerin, 0.5 gram paraffin, and some filter paper were treated in separate experiments, according to the procedure: nearly all the organic matter was decomposed by the first two or three treatments with H_2SO_4 and HNO_3, and after a few more treatments colorless solutions were obtained.

P. 2, N. 2. — See C. E., P. 5, N. 4 and 5.

P. 3, N. 7: Oxidation of Mercurous Salts by HNO_3. — 100 mgm. Hg as $Hg_2(NO_3)_2$ were boiled with a little HNO_3 (1.42) for one minute, the solution was diluted, and HCl added: no precipitate was formed, thus showing that the mercurous salts had been completely oxidized. 100 mgm. Hg as $Hg_2(NO_3)_2$ were boiled for 10 minutes with 25 ccm. HNO_3 (1.04), and HCl was added: a large precipitate of Hg_2Cl_2 resulted, showing that dilute HNO_3 does not oxidize a mercurous salt rapidly.

Volatility of Mercury and Arsenic Compounds. — Separate solutions containing 1 mgm. Hg as $HgCl_2$ in HNO_3, HCl, *aqua regia*, and H_2SO_4 were carefully evaporated just to dryness; the residue was in each case dissolved in a little water, and the solution saturated with H_2S: a precipitate of HgS estimated by comparison at not less than $\frac{2}{3}$ mgm. Hg was obtained in each case, showing that not much of the mercury had been volatilized. It was found that $HgCl_2$ was not converted into $Hg(NO_3)_2$ by the evaporation with HNO_3.

1 mgm. Hg as $HgCl_2$ was heated in a hot closet at 125°, the casserole was washed out with water, and the solution saturated with H_2S: no precipitate was obtained, thus showing that the $HgCl_2$ was completely volatilized.

1 mgm. Hg as $Hg(NO_3)_2$ was heated for two days at 125° in a hot closet, dissolved in water, and treated with H_2S: an HgS precipitate resulted, whose size indicated that little or none had volatilized.

10 mgm. As as As_2O_3 were added to 10 ccm. HCl (1.20), and the solution was boiled vigorously for about 15 seconds; the solution was somewhat diluted and then saturated with H_2S: only 1–2 mgm. As as As_2S_3 were precipitated.

The experiment was repeated, except that the HCl solution was evaporated to 2 ccm.: scarcely any precipitate of As_2S_3 was obtained. In another experiment the solution was evaporated to dryness: no precipitate of As_2S_3 formed.

A solution of 10 mgm. As as As_2O_3 in 10 ccm. H_2O and 2 ccm. HCl

(1.20) was boiled for 30 seconds and H_2S was passed in: a precipitate appearing like that given directly by 10 mgm. As was obtained, showing that very little if any arsenic was volatilized. A similar solution of 10 mgm. As was evaporated to 2 ccm.: it gave with H_2S a precipitate estimated to contain 3 mgm. As.

1 and 10 mgm. As as As_2O_3 dissolved in 5–10 ccm. HCl (1.20) were boiled in covered casseroles, oxidized with bromine water, evaporated to dryness, and dissolved in HCl; the solution was then precipitated with H_2S: the amount of arsenic precipitated was estimated to be nearly as great as that originally taken, thus showing that arsenic in the higher state of oxidation is not volatilized.

P. 3, N. 9–12: Solubility of the Dehydrated Hydroxides in HNO_3. — For this and for a statement as to other substances that the residue may contain, see A. A. Noyes, this QUARTERLY, **16**, pp. 121–126 (1903).

P. 4, N. 1: Solubility of $PbSO_4$, $BaSO_4$, AgCl, and $Sn(PO_4)_4$ in HCl. — See this QUARTERLY, **16**, p. 126 (1903).

Action of HCl and HNO_3 on AgCN and AgI. — 50 mgm. Ag as freshly precipitated AgCN were boiled with 20–30 ccm. HCl (1.20): the precipitate dissolved quickly.

To 50 mgm. Ag as freshly precipitated AgI were added 10 ccm. HNO_3 (1.42), and the mixture was evaporated, diluted, filtered, and HCl was added to the filtrate: a precipitate of AgCl estimated to contain 15 mgm. Ag was obtained, showing that AgI is slowly decomposed by HNO_3. The experiment was repeated with 50 mgm. Ag as AgCN: no precipitate of AgCl was obtained.

P. 4, N. 4: Solubility of Metastannic and Antimonic Acids in H_2SO_4 and HCl. — 200 and 400 mgm. Sn as metastannic acid, which had been heated for 1 hour in a hot closet at 120°, were treated in separate experiments with 3 ccm. concentrated H_2SO_4 as described in the Note: in the first case all the tin, in the second all but a few milligrams of it, dissolved on boiling the acid for about a minute. The solutions were diluted with 2–3 ccm. water and boiled: no precipitate formed. The first solution was cooled and poured into 10 ccm. cold water: a solution which remained clear for several hours was obtained, from which a white precipitate separated at once on boiling. To the other solution (containing 400 mgm. Sn) were added 5 ccm. HCl (1.12) and 50 ccm. water: no precipitate appeared, even on boiling. The solution was diluted to 200 ccm.: a white precipitate then formed. The precipitates obtained from these solutions dissolved readily in dilute HCl and in concentrated H_2SO_4.

200 mgm. Sb as hydrated Sb_2O_5, previously heated at 120°, were boiled with 5 ccm. HCl (1.12) for 2 or 3 minutes: complete solution resulted.

200 mgm. Sb as hydrated Sb_2O_5 did not dissolve in 3 ccm. boiling con-

centrated H_2SO_4 or on dilution, but dissolved readily when HCl was added as described in the Note. This solution was diluted with 10 ccm. water: a slight precipitate formed, which dissolved on the addition of a little HCl and warming.

In another experiment 200 mgm. Sn as dehydrated metastannic acid were boiled for about 30 minutes with HCl (1.20): at the end of that time the solid had dissolved nearly, but not quite completely.

Solubility of Metastannic, Antimonic, and Silicic Acids in Ammonium Sulphide. — 200 mgm. metallic antimony and 300 mgm. metallic tin were treated in separate experiments by P. 3 and the procedure described in Note 4: clear solutions were obtained on adding the acid solution to the alkaline ammonium sulphide solution.

The following experiments show that the residue from P. 3 may be treated directly with ammonium sulphide, but that this process is ordinarily a longer one than that described in the Note.

200 mgm. Sn as dehydrated metastannic acid, previously heated at 120°, were warmed gently with successive 10 ccm. portions of the ammonium polysulphide reagent in a covered casserole for 5–10 minutes, with frequent stirring: in the first treatment considerably more than half of the tin dissolved; after the second treatment only about 20 mgm. were left undissolved; and two more treatments dissolved this completely. — The experiment was repeated, using colorless ammonium monosulphide in place of the yellow polysulphide: the same results were obtained.

500 mgm. Sn as dehydrated metastannic acid were treated with successive 10 ccm. portions of yellow ammonium sulphide in a pressure bottle at 70–80°: practically all dissolved in two 10-minute treatments.

200 mgm. Sn as dehydrated metastannic acid dissolved in 10 ccm. ammonium monosulphide in a pressure bottle at 80° in about 10 minutes, and another portion of about 100 mgm. Sn dissolved in the same solution on further heating.

200 mgm. Sb as hydrated Sb_2O_5, previously heated at 120°, were treated in a covered casserole with ammonium polysulphide; it dissolved only very slowly, and several treatments were necessary to effect complete solution. As with metastannic acid, the use of the pressure bottle hastened the solution, but antimonic acid dissolved even less readily than metastannic acid.

100 mgm. dehydrated silicic acid were warmed for 15 minutes with 20 ccm. ammonium monosulphide; the filtrate was acidified, evaporated to dryness, and tested for silica by P. 5: very little, if any, gas evolution was obtained, thus showing that SiO_2 is insoluble in ammonium sulphide. — In another experiment only a few milligrams (1–3) SiO_2 dissolved in 30 ccm. boiling ammonia (0.96) in 15 minutes.

P. 5, N. 2: The Test for SiO_2 with HF and H_2SO_4. — 1 and 2 mgm. of

dehydrated H_2SiO_3 were treated as described in the first paragraph of P. 5: evolution of gas took place at room temperature and was easily seen in both cases.

1 and 2 mgm. SiO_2 as feldspar, which had been well purified from free silica by long-continued boiling with Na_2CO_3 solution, were treated in separate experiments according to P. 5: there was no evolution of gas in the cold, but a distinct one took place on warming.

500 mgm. $BaSO_4$, 100 mgm. TiO_2, 100 mgm. tantalic acid, and 150 mgm. niobic acid were treated by P. 5: no evolution of gas was observed in the cold nor on warming, provided the solid had been previously heated with the strong H_2SO_4 to remove air bubbles.

A filter (Schleicher und Schüll, No. 597) 11 cm. in diameter, with an ash stated to be 0.0028 gram, was treated by P. 2, to destroy organic matter, and the residue by P. 5, to test for silica: bubbles of gas were clearly seen.

In a series of experiments an attempt was made to test for silica by adding HF to the dry solid and allowing the SiF_4 evolved to act on a drop of water held in the loop of a platinum wire near the solid. The best conditions were found to be to add less HF than corresponded to the silica present, to allow the reaction to continue until almost all the HF was destroyed, the action being accelerated by stirring with a heavy platinum wire, and then to warm the mixture gently, while holding the drop of water near the solid. Even under these conditions, however, the drop did not become turbid when less than 5 mgm. SiO_2 were used, although an evolution of gas doubtless took place, as was shown by a hissing sound.

P. 5, N. 3: Action of Hot H_2SO_4 on Platinum. — 5 ccm. H_2SO_4 (1.84) were evaporated to 2 ccm. in an open platinum crucible within 2 or 3 minutes, cooled, diluted with 5–10 ccm. water, and H_2S passed into the hot solution for some minutes: a brown coloration appeared quickly, but no precipitate settled out.

5 ccm. H_2SO_4 (1.84) were boiled for 15 minutes in a covered platinum dish previously weighed, cooled, diluted, and saturated hot with H_2S: a precipitate of PtS_2 estimated to contain 2–3 mgm. Pt was obtained and the dish had lost 3 mgm. in weight.

P. 5, N. 4: Action of H_2SO_4 and HF on Minerals and Other Substances. — Each of the following substances was treated with the stated result by the following procedure, which is similar to the regular process, P. 4–6, except that in these experiments the substance was digested for a longer time with hot concentrated H_2SO_4. 1 gram was digested for several minutes in a covered platinum dish with 10 ccm. HNO_3 (1.42). 3 ccm. H_2SO_4 (1.84) were then added, the mixture was evaporated to distinct fuming, and maintained at that point for 10 minutes. 5 ccm. HF were added, the mixture was digested for 15 minutes on a water bath, and then evaporated until

thick acid fumes were given off; 3 ccm. HF were added, and the mixture was again evaporated to fuming. 30 ccm. water were added, the mixture was boiled for 15 minutes, cooled, diluted to 100 ccm., and the residue washed once by decantation. 30 ccm. saturated Na_2CO_3 solution were then poured over the residue, and the mixture was allowed to stand, with frequent stirring, for 15 minutes. The solution was decanted, and the residue washed twice with water, after which it was treated with 30 ccm. HCl (1.02). A large residue was left after the final treatment with HCl by cassiterite (SnO_2), emery (Al_2O_3), chromite ($FeO.Cr_2O_3$), rutile (TiO_2), cinnabar (HgS), molybdenite (MoS_2), tourmaline, beryl ($Be_3Al_2Si_6O_{18}$), and columbite ($Fe(Nb,Ta)_2O_6$). About a third of the molybdenite was decomposed by the HNO_3 with separation of some molybdic acid, which dissolved in the H_2SO_4. Cinnabar, rutile, and beryl were much attacked by H_2SO_4, and columbite by HF, but the other substances were attacked not at all, or only very slightly, by any of the reagents. — Fluorspar (CaF_2), chrome yellow ($PbCrO_4$), wulfenite ($PbMoO_4$), and vanadinite ($3Pb_3V_2O_8.PbCl_2$) were attacked by HNO_3 and by H_2SO_4; titanite ($CaTiSiO_5$), garnet ((Ca, Mg, Mn,Fe)$_3Al_2Si_3O_{12}$), a cement, and some slags containing lead or calcium, were attacked by these acids and also by HF. All left, after the treatment with HF and H_2SO_4, a white residue, which, after the treatment with Na_2CO_3, dissolved completely in HCl. The white residue, therefore, contained only insoluble sulphates, such as $PbSO_4$, $CaSO_4$; and the substances were completely decomposed by the treatment with HNO_3, H_2SO_4, and HF. — Wolframite ((Fe, Mn)WO_4), menaccanite ($FeTiO_3.Fe_2O_3$), and Prussian blue were decomposed by H_2SO_4, and all left a residue insoluble in dilute H_2SO_4, which dissolved completely, or nearly so, in Na_2CO_3. — Magnetite (Fe_3O_4), cryolite (Na_3AlF_6), basalt, granite, monazite, a uranium ore, and a number of slags were completely decomposed after the treatment with HNO_3, H_2SO_4, and HF, and dissolved completely in the dilute H_2SO_4.

For the action of HF and HNO_3 on some other difficultly soluble native silicates, see this QUARTERLY, **16**, p. 126 (1903).

P. 5, N. 4 and 5: Solubility of Sulphates in Concentrated and Dilute H_2SO_4. — 100 mgm. and 150 mgm. Ba as $BaSO_4$ were strongly heated with 2 ccm. concentrated H_2SO_4: a clear solution resulted in the first case, but not in the second. $BaSO_4$ was precipitated at once when a little water was added.

For the solution of $PbSO_4$ in concentrated H_2SO_4, see C. E. on P. 26, N. 1.

10, 15, and 20 mgm. Ca as $Ca(NO_3)_2$ were added in separate experiments to 20 ccm. H_2SO_4 (1.20): with the 20 mgm. a precipitate separated at once and with the 15 mgm. after about 5 minutes, while with the 10 mgm. none formed, even after several hours.

300 mgm. Al, 300 mgm. Fe, 100 mgm. mercuric Hg, and 150 mgm. Cu,

all as sulphates, were in separate experiments boiled with concentrated H_2SO_4, cooled, diluted, and again boiled as described in the procedure: the anhydrous $Al_2(SO_4)_3$ and $Fe_2(SO_4)_3$ dissolved completely after about 3 minutes' boiling: the anhydrous $CuSO_4$ and the $HgSO_4$ dissolved at once on warming.

To 100 mgm. Cr as $Cr_2(SO_4)_3$ in solution as green sulphate 2 ccm. H_2SO_4 (1.84) were added, and the solution was evaporated until thick acid fumes came off; the mixture was cooled, diluted, and boiled, the whole treatment being as in the Procedure: the resulting solution was green, and from its color was estimated to contain 10–15 mgm. Cr; the remainder of the chromium was left as a very finely divided light-pink powder (anhydrous $Cr_2(SO_4)_3$). — This experiment was repeated, except that the H_2SO_4 was heated only until slight fumes appeared: no pink precipitate separated, and on boiling with water a clear green solution was obtained.

100 and 200 mgm. Cr as precipitated $Cr(OH)_3$ were dissolved in 5 ccm. H_2SO_4 (1.84) and 20 ccm. water; the solutions were evaporated to about 2 ccm., cooled, diluted, again boiled, and filtered: a very finely divided, gray to pink powder (anhydrous $Cr_2(SO_4)_3$) was obtained, which ran through the filter. The precipitate was allowed to settle and the solution was decanted and boiled with NH_4OH: it was colorless and gave scarcely any precipitate of $Cr(OH)_3$. The anhydrous sulphate was boiled for 15 minutes with dilute H_2SO_4: only a few milligrams dissolved. The sulphate was found to be slowly dissolved by a concentrated Na_2O_2 solution owing to oxidation to chromate.

500 mgm. Sb as $SbCl_3$, 50 mgm. antimonic Sb ($SbCl_3$ previously boiled with HNO_3 and HCl), and 500 mgm. Bi as $Bi(OH)_3$ were heated in separate experiments with 3–5 ccm. H_2SO_4 (1.84), evaporated to 2 ccm., diluted to about 20 ccm., and again boiled. With the antimonous salt a crystalline precipitate was obtained on evaporating the H_2SO_4 solution; this precipitate dissolved when the 20 ccm. water were added, but an amorphous precipitate formed when much more water was added. The antimonic antimony was precipitated in the concentrated H_2SO_4 as an amorphous powder, and more of this precipitate separated on dilution; the dilute H_2SO_4 solution was filtered and the amount of antimony contained in the filtrate was estimated by precipitating with H_2S to be about 10 mgm.; the residue insoluble in H_2SO_4 was washed with water and dissolved in boiling HCl, and to the solution $BaCl_2$ was added: only a slight precipitate of $BaSO_4$ was formed, showing that the residue was an oxide or hydroxide, not a sulphate. In the experiment with bismuth the hydroxide dissolved in H_2SO_4, and a crystalline precipitate (sulphate) separated from the hot concentrated H_2SO_4, but the larger part of this dissolved on adding the water, provided the solution was kept cold; a precipitate (of oxysulphate)

appeared when this solution was heated; the filtrate from this was treated with NH_4OH, and a precipitate was obtained which was estimated to contain 20–50 mgm. Bi.

P. 5, N. 6: Decomposition of Silver Salts by H_2SO_4. — 500 mgm. Ag as precipitated AgCl, 500 mgm. Ag as fused AgCl, 100 mgm. Ag as precipitated AgCN, and 100 mgm. Ag as precipitated AgI were treated with H_2SO_4 as described in P. 5: there was a residue in each case. HCl was added to the H_2SO_4 solution: a small precipitate of AgCl was then obtained, showing that some of the silver salt had been decomposed. The residues were boiled with 5 ccm. H_2SO_4 (1.84) in a covered casserole for several minutes: AgI and AgCN dissolved readily in less than 5 minutes, and almost all the AgCl in less than 10 minutes.

500 mgm. Ag as AgCl were boiled with Na_2CO_3 solution (as described in P. 6) for 15 minutes: the AgCl precipitate quickly turned black. The Na_2CO_3 solution was acidified with HNO_3, and $AgNO_3$ added: a precipitate of AgCl, estimated to contain 2 mgm. Ag, formed, showing that only this amount of Ag as AgCl had been converted into silver oxide.

Action of H_2SO_4 on Al_2O_3 and TiO_2. — 2 grams coarsely powdered corundum, which had been previously digested with HF, and 0.5 gram rutile were in separate experiments boiled with 10 ccm. H_2SO_4 (1.84) in a covered casserole for 15 minutes; the mixture was diluted, filtered, and the filtrate made alkaline with NH_4OH: about 50 mgm. Al and about half the titanium were precipitated as hydroxides.

100 mgm. Al as Al_2O_3, obtained by igniting $Al(OH)_3$, were boiled with 5 ccm. H_2SO_4 (1.84) in a covered casserole for 10 minutes: a residue containing 10–20 mgm. Al was left undissolved, and this did not dissolve completely on two more treatments with H_2SO_4. — The experiment was repeated with 200 mgm. Ti as ignited TiO_2: nearly all of it dissolved in 3–4 minutes.

P. 6, N. 1: Action of Boiling Sodium Carbonate Solution on $BaSO_4$, $Cr_2(SO_4)_3$, and Sb_2O_5. — 500 mgm. Ba as $BaSO_4$ were treated by the procedure: a residue of $BaSO_4$ corresponding to about 30 mgm. Ba remained on adding HCl. This residue was treated a second time by the procedure: not more than 1–2 mgm. Ba as $BaSO_4$ then remained.

100 and 200 mgm. Cr as anhydrous $Cr_2(SO_4)_3$, obtained as described under C. E., P. 5, N. 4 and 5, were boiled with Na_2CO_3 in a covered casserole as described in P. 6: the pink precipitate slowly became greenish blue in color. The Na_2CO_3 solution was acidified with HCl, and $BaCl_2$ added to it: a precipitate of $BaSO_4$ was formed, thus showing that chromic sulphate was being decomposed.

The greenish blue residue from the experiment with 100 mgm. Cr (which in contrast to the anhydrous sulphate filtered easily) was boiled with HCl:

some chromium dissolved, but the greater part was left as undecomposed anhydrous sulphate.

The greenish blue residue from the experiment with 200 mgm. Cr was boiled for about 2 hours with seven successive portions of Na_2CO_3 solution, and these solutions were tested for sulphate. The sulphate in these portions steadily decreased in amount and the last portion was free from it. The greenish blue residue now dissolved completely in HCl on warming, and the solution gave no precipitate with $BaCl_2$, showing that the chromic sulphate had been completely converted into the hydroxide.

100 mgm. Sb as antimonic hydroxide, obtained as described under C. E., P. 5, N. 4 and 5, were boiled with 25 ccm. Na_2CO_3 solution in a covered casserole for 15 minutes; the solution was acidified, and treated with H_2S: an orange precipitate of sulphide was obtained which was estimated to contain 3–4 mgm. Sb.

**P. 6a, N. 1: Precipitation of H_2WO_4 from Na_2CO_3 Solution by Acids.* — 1 mgm. W as Na_2WO_4 was added in separate experiments to 5 ccm. H_2O, to 5 ccm. saturated Na_2CO_3 solution, and to 20 ccm. Na_2CO_3 solution; HNO_3 was added in excess and the solutions evaporated almost to dryness: yellow H_2WO_4 separated in the presence of HNO_3 alone, but not in the solutions containing $NaNO_3$. The latter were diluted with enough hot water to dissolve the salt, 1–2 ccm. HNO_3 (1.20) were added, the solutions were boiled vigorously and then cooled: yellow H_2WO_4 precipitated in the solution containing the smaller amount of salt, but not in the other solution. — The experiment with 20 ccm. Na_2CO_3 solution was repeated except that 2 mgm. and 3 mgm. W (in separate experiments) were taken: no yellow precipitate was obtained with 2 mgm., and only a slight one with 3 mgm., thus showing that the presence of $NaNO_3$ interferes with the test.

Solutions containing, respectively, 1, 2, 5, 10, and 20 mgm. W as Na_2WO_4 in 20 ccm. Na_2CO_3 solution were evaporated with excess of H_2SO_4 to strong fuming, diluted to about 15 ccm., boiled, and cooled again: no yellow precipitate was formed in any of the experiments. — Solutions containing 2, 3, 5, and 10 mgm. W as Na_2WO_4 in 20 ccm. Na_2CO_3 solution were evaporated with excess of HCl almost to dryness, diluted to about 15 ccm., boiled, and cooled: no yellow precipitate was formed. The final solutions obtained in all these experiments turned blue when some granules of zinc were added, though the color from 1 mgm. W in H_2SO_4 appeared only after several minutes.

P. 6a, N. 2.: Reduction of H_2WO_4 with Zinc.* — See v. d. Pfordten, *Ber. d. chem. Ges.*, **16, 508 (1883).

To 10 mgm. W as Na_2WO_4 in a test tube were added 5 ccm. water, 5 ccm. HCl (1.12), and a few granules of zinc: a white precipitate separated when HCl was added, and a deep blue color resulted from the action of the

zinc; after half an hour the blue color had changed to a dark brown, and a dark-colored precipitate was suspended in the solution.

**P. 6a, N. 3: Solubility of H_2WO_4 in Acids.* — 2 mgm. W as Na_2WO_4 were treated by P. 3, 4, and 5 except that no HF was added: a yellow precipitate of H_2WO_4 was obtained on boiling with HNO_3 and was not dissolved by dilute HNO_3 after the evaporation (P. 3); the residue dissolved in HCl (1.20) on boiling, but H_2WO_4 was reprecipitated on evaporating the *aqua regia* and was not dissolved by the dilute HCl (P. 4). Nearly all the residue dissolved, however, in 2 ccm. H_2SO_4 (1.84) and did not reprecipitate on diluting to 20 ccm. and boiling (P. 5). — For the solubility of H_2WO_4 in concentrated H_2SO_4 and after dilution, see this QUARTERLY, 17, 249 (1904).

P. 7, N. 2: Effect of fusing Al_2O_3, SnO_2, TiO_2, MoS_2 with Na_2CO_3 or with Na_2CO_3 and KNO_3. — For the fact that a large residue remains when native Al_2O_3, TiO_2, and SnO_2 are fused with Na_2CO_3, see this QUARTERLY, 16, 127 (1903).

80 mgm. Al as Al_2O_3, obtained by igniting precipitated AlO_3H_3 over a blast lamp for 15 minutes, were fused with 8 grams Na_2CO_3 in a platinum crucible over a powerful burner for 20 minutes; 0.2 gram KNO_3 was then added and the heating continued for 10 minutes longer; the fusion was cooled and digested with HCl: only a small residue of unattacked Al_2O_3, corresponding to 5–10 mgm. Al, remained. The solution gave no precipitate with H_2S, showing that platinum had not been removed from the crucible.

500 mgm. Mo as molybdenite (MoS_2) were fused for 3–5 minutes in a porcelain crucible with 10 grams Na_2CO_3 and the mass treated with water: the black particles of MoS_2 all dissolved during the fusion, and the mass, which had a light red color, dissolved nearly completely in water. HCl was added to the solution: a large black precipitate separated.

150 mgm. Mo as molybdenite were fused for about 2 minutes in a platinum crucible with 8 grams Na_2CO_3 and 0.5 gram KNO_3, and the mass was treated with dilute HCl: complete solution resulted; the platinum crucible was not injured. — The experiment was repeated except that the KNO_3 was added after a minute's fusion with Na_2CO_3: the result was the same.

P. 7, N. 2 and P. 8, N. 3: Effect of Fusing Al_2O_3, SnO_2, TiO_2 with KOH. — 200 mgm. of coarsely powdered corundum (Al_2O_3) that had been previously digested with HF and with concentrated H_2SO_4 and 200 mgm. of finely powdered cassiterite (SnO_2) were fused with 10 grams KOH in nickel crucibles for 15 minutes; the mass was extracted with water and the residue heated with HCl: a residue still remained, which was estimated to contain about half the Al_2O_3, but little, if any, of the SnO_2. An analysis was made of the aqueous extract and of the HCl solution: the former was found to contain about 50 mgm. Al (as aluminate) and 100–150 mgm. Sn

(as stannate), but no nickel; the HCl solution contained 20–40 mgm. Sn, 10–15 mgm. Ni, and some Fe as chlorides, but no other metallic element.

1 gram of rutile containing 600 mgm. Ti was treated by P. 3, 4, and 5; the residue was fused with KOH for about 5 minutes as described in P. 7. N. 3; the mass was extracted with water, and the residue treated with cold HCl (1.12): the rutile was not attacked by HNO_3 (P. 3) nor by HNO_3 and HCl (P. 4), but about 300 mgm. Ti were dissolved by H_2SO_4 and HF (P. 5); much of the TiO_2 dissolved in the fused KOH, but only 2–3 mgm. Ti passed into solution on treating the mass with water; out of the residue, which consisted of a black and white mixture, about 200 mgm. Ti dissolved on treating with HCl (1.12); and a black residue of unattacked rutile still remained, which weighed 150 mgm., corresponding to about 90 mgm. Ti. This was powdered finely, again fused with KOH for 15 minutes, and extracted with dilute HCl: all but 3–4 mgm. Ti dissolved.

P. 8, N. 3: Foreign Substances Introduced from Porcelain or Nickel Crucibles. — 10 grams of a mixture of K_2CO_3 and Na_2CO_3 were fused in a porcelain crucible for half an hour over a powerful burner, the mass treated as described in the procedure, and the residue and solution analyzed separately: the residue after the evaporation to dryness with HCl was shown by P. 5 to contain several milligrams of SiO_2; the solution was found to contain several milligrams of aluminum and of calcium and a trace of iron. Compare also C. E., P. 8, N. 5 below.

The experiment was repeated, using a nickel crucible: the aqueous extract acidified with HCl gave no precipitate with H_2S nor with NH_4OH and $(NH_4)_2S$. A slight black residue of nickel oxide insoluble in water remained: this dissolved in HCl and gave a precipitate with NH_4OH and $(NH_4)_2S$, which was estimated to contain 1 mgm. Ni. — This experiment was repeated, except that 0.3 mgm. KNO_3 was added to the fusion: 4–5 mgm. Ni as nickel oxide were obtained.

Reduction of Silver and Lead Compounds by Fusion in a Nickel Crucible.— 200 mgm. Ag as precipitated AgCl were fused with 10 grams of a mixture of Na_2CO_3 and K_2CO_3 in a nickel crucible for 10 minutes and the mass extracted with water: a residue of bright-colored metallic silver soluble in HNO_3 was left as a loose mass which did not adhere to the crucible, there being no evidence of the formation of an alloy.

200 mgm. Pb as precipitated $PbSO_4$ were fused as in the preceding experiment: neither the aqueous extract (when acidified with HCl) nor the HCl solution of the residue gave precipitates with H_2S. The lead salt was completely reduced to metallic globules which had melted on to the nickel crucible, and were not dissolved off by fusion with KOH, KOH and KNO_3, KOH and Na_2O_2, or Na_2O_2 alone.

P. 8, N. 5: Behavior of Antimony and Tin Compounds on Fusion with

Sodium Carbonate. — 60 mgm. Sn as $SnCl_2$ and 50 mgm. Sb as $SbCl_3$ were fused in a porcelain crucible with 10 grams of a mixture of K_2CO_3 and Na_2CO_3 for half an hour; the fusion was extracted with water and with HCl as described in the procedure, and the solutions separately analyzed: the aqueous extract contained nearly all the antimony and tin, a few milligrams of silica, aluminum, and a little calcium; the HCl solution contained 4–5 mgm. antimony, and 1–2 mgm. each of aluminum, iron, and calcium.

PART II. ANALYSIS OF THE SILVER, COPPER, AND TIN GROUPS

General Discussion

A survey of the main features of the method adopted for the analysis of the hydrochloric acid and hydrogen sulphide precipitates may be obtained by referring to the "Tabular Outline" following this chapter. Here only the modifications introduced into the process ordinarily followed will be discussed.

In the precipitation and analysis of the silver group the usual process has been adhered to, the only addition being a provision for the detection of thallium by removing the lead with sulphuric acid and then adding potassium iodide.

In the directions for the precipitation of the copper and tin groups by hydrogen sulphide, especial attention is given to securing the proper conditions as to acid concentration and temperature for a satisfactory separation of these elements from those of the iron group; for indefiniteness in this respect is one of the most common sources of difficulty to the inexperienced analyst. In our process, as will be seen by reference to P. 21, it is directed to precipitate first from a hot, moderately acid solution. The fairly large acid concentration has the advantage of preventing the precipitation by hydrolysis of basic salts of titanium, bismuth, and antimonous antimony, and of hastening the precipitation of the arsenic. The high temperature promotes the precipitation of arsenic, molybdenum, and platinum, and causes all the sulphides to separate in a more readily filterable form. The solution is, however, finally diluted so as to contain 4 ccm. of hydrochloric acid of specific gravity 1.12 in 100 ccm., and is saturated with hydrogen sulphide in the cold; for only with an acid as dilute as this and then in the cold is it possible to precipitate as little as 1 or 2 mgm. of cadmium or lead.

Attention may be called to our experiments described in the chapter on "Confirmatory Experiments and References," which show that under these conditions the separation is a remarkably satisfactory one —at any rate from a qualitative analysis point of view, since not only is the precipitation of the copper and tin groups complete, but one milligram of zinc, iron, or nickel is found in the filtrate, even when 500 milligrams of cadmium, copper, or tin are present.

In the case of substances originally dissolved without the use of nitric acid, which may therefore contain tin or antimony in the stannous or antimonous state, the hydrogen sulphide precipitate is, as usual, treated with ammonium polysulphide. The separation of certain elements by this reagent is, however, far from complete. Thus copper and mercury dissolve in not insignificant quantity in the polysulphide; and tin may remain entirely undissolved, even when several milligrams are present, if cadmium, copper, or mercury is also present in large quantity; moreover, gold, platinum, and the elements allied to them divide themselves between the residue and solution to so large an extent and to so different an extent in different combinations, as to make this reagent entirely unsatisfactory for separating these elements; and with molybdenum the solution is seldom complete, though a large proportion of it always dissolves. New experiments confirmatory of these already known facts will be found described below in the chapter on "Confirmatory Experiments." Yet in a scheme devoted primarily to the common elements there seems to be no alternative process of separation which, on the whole, is nearly so satisfactory; especially since it is not difficult to separate tin from the elements of the copper group in the course of the analysis of the latter, and since enough copper and mercury always remain undissolved by the ammonium polysulphide to enable as little as two milligrams to be detected.

In the case of substances not completely soluble in water, the treatment with nitric acid, recommended in Part I, converts tin and antimony into the higher state of oxidation; and this makes it practicable, as our experiments have shown, to substitute ammonium monosulphide for the polysulphide in the case of such substances, which constitute by far the larger proportion of those ordinarily submitted to analysis. This has the advantage of not dissolving cupric and mercuric sulphides appreciably, thereby not only making the tests for copper and mercury more delicate, but also making it possible to decide with certainty from the appearance of the precipitate produced by acid in the ammonium

sulphide solution whether or not any element of the tin group is present. The monosulphide has, of course, the same defects as the polysulphide in not completely extracting tin and the rarer elements, but not in any more marked degree when these elements are in the higher state of oxidation. This will be evident by reference to the "Test Analyses of the Tin Group."

In the process of analysis of the copper group (see Table V) the only important modification introduced has reference to the extraction of the tin, which may, as just stated, remain wholly in the residue undissolved by ammonium sulphide. The residue undissolved by nitric acid, which may consist of mercuric sulphide and metastannic acid, is treated with bromine water instead of with an acid oxidizing mixture, in order to dissolve out the mercury and leave behind the tin, which can then be dissolved in ammonium sulphide and united with the main solution of the tin group.

For the analysis of the tin group various processes have been proposed and are in general use. As will be seen from Table VI, the method of separation here adopted is based entirely on the different solubilities of the three sulphides of arsenic, antimony, and tin in hydrochloric acid of varying concentration. This process, which seems to have been first suggested for the separation of antimony and tin by Loviton (*J. Chem. Soc.*, 54, 992. 1888), and which has been utilized in part by Bailey and Cady in their text-book on qualitative analysis, we have somewhat developed by a detailed study of the best conditions for making it a good qualitative method. We believe this method is the one best adapted to the purposes of ordinary qualitative analysis, because of its great simplicity, and because of the fact that the tests, while being of sufficient delicacy to detect one milligram of any of these elements, do not have in the case of arsenic and antimony the extreme sensitiveness of the reduction tests based on the decomposition by heat of hydrogen arsenide and antimonide.

Of the rarer elements precipitable by hydrogen sulphide, provision has been incidentally made for the detection of all the more important ones, namely for that of molybdenum, selenium, tellurium, gold, and platinum. The treatment with hot concentrated hydrochloric acid employed for separating the sulphides of antimony and tin from that of arsenic makes such provision comparatively simple; for the sulphides of all these rarer elements are left, with that of arsenic, together at one place in the scheme (except that gold and platinum may also remain

in the copper group residue, and have to be tested for also in the analysis of that group). No attempt has been made to include the other so-called platinum elements, since the reliable detection of these can be effected only by a special and complicated process. These elements will be treated in the "System of Analysis Including Nearly All the Metallic Elements," which is being published in this QUARTERLY.

TABULAR OUTLINE

TABLE IV

ANALYSIS OF THE SILVER GROUP

Precipitate: $AgCl$, Hg_2Cl_2, $PbCl_2$, *$TlCl$. *Treat with hot water* (*P. 12*).

Solution: $PbCl_2$, *$TlCl$. *Add H_2SO_4 (P. 13).*		Residue: $AgCl$, Hg_2Cl_2. *Pour NH_4OH through the filter (P. 15).*	
Filtrate: *Tl_2SO_4. *Add KI (*P. 13a).*	Precipitate: $PbSO_4$. *Dissolve in $NH_4C_2H_3O_2$, add K_2CrO_4 (P. 14).*	Black Residue: $HgNH_2Cl + Hg$.	Solution: $Ag(NH_3)_2Cl$. *Add HNO_3 (P. 15).*
Yellow precipitate: *TlI.	Yellow precipitate: $PbCrO_4$.		White precipitate: $AgCl$.

TABLE V

Analysis of the Copper Group

H_2S PRECIPITATE: HgS, PbS, Bi_2S_3, CuS, CdS, As_2S_3, As_2S_5 (with As_2S_3 and S_2), Sb_2S_3, Sb_2S_5, SnS, SnS_2, *PtS_2, *Au and *Au_2S_{1-3}, *Se, *Te (and TeS_2?), *MoS_{2-3}.
Digest with ammonium sulphide (*P. 22*).

Residue: HgS, PbS, Bi_2S_3, CuS, CdS, [*PtS_2], [*Au and Au_2S_{1-3}], [*MoS_{2-3}]. *Boil with HNO_3* (*P. 23*).

Solution: $(NH_4)_3AsS_4$, $(NH_4)_3SbS_4$, $(NH_4)_2SnS_3$, *$(NH_4)_2PtS_3$ (?), *$(NH_4)_3AuS_3$ (?), *$(NH_4)_2SeS_3$ (?), *$(NH_4)_2TeS_3$ (?), *$(NH_4)_2MoS_4$. *Add HCl* (*P. 41*).

Precipitate: See Table VI.

Residue: HgS, SnO_2, *Au and *Au_2S_{1-3}, *PtS_2. *Add Br_2 solution* (*P. 24*).

Solution: Pb, Bi, Cu, Cd as nitrates. *Add H_2SO_4, evaporate, add water* (*P. 26*).

Residue: SnO_2. *Dissolve in $(NH_4)_2S$* (*P. 25*). *Unite with tin group* (*P. 41*).

Solution. *Add KCl, evaporate to a small volume* (**P. 24a*).

Yellow precipitate: *K_2PtCl_6.

Filtrate. *Add NaOH and $H_2C_2O_4$, and heat* (**P. 24a*).

Purple precipitate: *Au.

Solution. *Add $SnCl_2$* (*P. 24*).

White or gray precipitate: Hg_2Cl_2 or Hg.

White precipitate: $PbSO_4$. *Dissolve in ammonium acetate, add K_2CrO_4* (*P. 14*).

Yellow precipitate: $PbCrO_4$.

Filtrate. *Add NH_4OH* (*P. 27*).

Precipitate: $Bi(OH)_3$. *Dissolve in HCl, evaporate, add to water* (*P. 28*).

White precipitate: BiOCl. *Add Na_2SnO_2.*

Black residue: Bi.

Filtrate: $Cu(NH_3)_4SO_4$ (blue), $Cd(NH_3)_4SO_4$.

To a small part add CH_3COOH and $K_4Fe(CN)_6$ (*P. 29*).

Red precipitate: $Cu_2Fe(CN)_6$.
White precipitate: $Cd_2Fe(CN)_6$.

To the remainder add KCN and H_2S (*P. 30*).

Yellow precipitate: CdS.

TABLE VI

ANALYSIS OF THE TIN GROUP

PRECIPITATE FROM AMMONIUM SULPHIDE SOLUTION: As_2S_5, Sb_2S_5, SnS_2, *PtS_2, *Au_2S_{3-6}, *SeS_2 (?), *TeS_2 (?), *MoS_3. *Heat with 10 ccm. HCl (1.20) (P. 42).*

Solution: $SbCl_5$. $SnCl_4$. *Dilute to 50 ccm., heat, and pass in H_2S (P. 45).*

Residue: As_2S_5. *PtS_2, *Au, *Se, *Te, *MoS_3. *Dissolve in HCl and $KClO_3$, evaporate to a small volume (P. 43).*

Orange precipitate: Sb_2S_3. *Dissolve in HCl, add Zn and Pt (P. 46).*

Black deposit: Sb. *Treat with NaOCl.*

Black deposit: Sb.

Solution: $SnCl_4$. *Cool, dilute, pass in H_2S (P. 47.)*

Yellow precipitate: SnS_2. *Dissolve in HCl, add Zn (P. 47).*

Gray deposit: Sn. *Dissolve in HCl, add $HgCl_2$ (P. 47).*

White precipitate: Hg_2Cl_2.

Yellow precipitate: *K_2PtCl_6. *Dissolve in hot water, add KI (*P. 43a).*

Dark red color: *K_2PtI_6.

Filtrate: H_3AsO_4, *$AuCl_3$, *H_2SeO_3, *H_2TeO_3, *H_2MoO_4. *Add NH_4OH, NH_4Cl, and $MgCl_2$ (P. 44).*

White precipitate: $MgNH_4AsO_4$. *Dissolve in HCl, add H_2S (P. 44).*

Yellow precipitate: As_2S_5, As_2S_3, and S.

Filtrate. *Heat with $H_2C_2O_4$, filter (*P. 43b).*

Purple or dark yellow precipitate: *Au.

Filtrate. *Evaporate, add strong HCl and Na_2SO_3 (*P. 43c).*

Red precipitate: *Se.

Filtrate. *Add water and KI (*P. 43d).*

Black precipitate: *Te.

Filtrate. *Boil off SO_2, add KCNS and Zn (*P. 43e).*

Deep red color: *$Mo(CNS)_4$.

PROCEDURES AND NOTES

Analysis of the Silver Group

Procedure 11. — To the cold aqueous solution of the substance (P. 3) add 4 ccm. HCl (1.12) from a small graduate. (White precipitate, presence of SILVER GROUP.) Filter, and wash the precipitate with a small quantity of cold water, adding the washings to the filtrate until its volume is about 40 ccm. (Precipitate, P. 12; filtrate, P. 21.)

Notes. — 1. Nonformation of a precipitate proves absence of silver and mercurous mercury, but not of lead (or thallous thallium), since $PbCl_2$ (and TlCl) are fairly soluble in water. Owing to the common-ion effect, the solubility of the chlorides is greatly decreased by the addition of HCl; but 20–40 mgm. Pb (and 5–15 mgm. Tl) may remain in solution, and thus escape detection in this group.

2. Since the subsequent precipitation of the copper and tin groups by H_2S must be made in a dilute HCl solution of known strength, a definite amount of HCl is added at this point and the solution is diluted to a known volume.

3. The addition of the first few drops of HCl may cause the precipitation of the white oxychlorides BiOCl and SbOCl; but these precipitates dissolve when the rest of the acid is added. If, however, the solution were largely diluted with water, the precipitate might again separate.

4. From an alkaline solution HCl might precipitate many other substances, as described in P. 3, N. 4. Such a solution is, therefore, first treated with HNO_3 (P. 3).

Procedure 12. — Pour repeatedly through the filter containing the HCl precipitate (P. 11) a portion of 10–20 ccm. boiling water. Wash the residue thoroughly with hot water. (Residue, P. 15; solution, P. 13.)

Procedure 13. — Add to the aqueous extract from the HCl precipitate (P. 12) one-fifth its volume of concentrated H_2SO_4; cool, shake the mixture, and allow it to stand for 5 minutes. (White precipitate, presence of LEAD.) Filter, wash the precipitate with H_2SO_4 (1.20) and then with a little water. (Precipitate, P. 14; filtrate, reject or test for thallium by * P. 13*a*.)

Note. — 1. $PbSO_4$ is slightly soluble in water, but, owing to the common-ion effect, much less so in dilute H_2SO_4; hence H_2SO_4 is added in excess to the solution and to the wash water.

* **Procedure 13a.** — To test for thallium add to the filtrate from the H_2SO_4 precipitate (P. 13) 2–3 ccm. KI solution. (Yellow precipitate, presence of THALLIUM.) If the solution becomes brown, owing to the liberation of free iodine, add a little H_2SO_3 solution.

**Notes.* — 1. Thallous iodide is much less soluble than the corresponding chloride, and its solubility is greatly decreased by KI, owing to the common-ion effect. PbI_2 is also difficultly soluble, but cannot be precipitated here, since lead has been removed by H_2SO_4 in P. 13. The presence of even 0.5 mgm. thallous thallium in 15 ccm. of solution may easily be detected in the cold by means of KI. Free iodine oxidizes thallous to thallic salts, but these, as well as the iodine itself, are reduced by H_2SO_3.

2. Thallous salts are oxidized to thallic salts rapidly by halogens and *aqua regia*, and slowly by hot concentrated HNO_3. Upon evaporating a thallic chloride ($TlCl_3$) solution and heating the residue at 120°, more or less complete reduction takes place by decomposition into TlCl and Cl_2. Pure thallic salts give no precipitate with HCl, thallous salts a white one; while mixtures of them give yellow precipitates ($TlCl_3.xTlCl$). For these reasons, even when the substance has been dissolved in HNO_3 and the solution has been evaporated as described in P. 4, thallium will be precipitated with this group by HCl if much of it is present.

Procedure 14. — Pour repeatedly through the filter containing the H_2SO_4 precipitate (P. 13) a 10–20 ccm. portion of a 10% ammonium acetate solution; add to the filtrate a few drops K_2CrO_4 solution and 2–5 ccm. dilute acetic acid. (Yellow precipitate, presence of LEAD.)

Notes. — 1. The solubility of $PbSO_4$ in solution of ammonium acetate ($NH_4C_2H_3O_2$) depends on the formation by metathesis of undissociated lead acetate, which is much less ionized than most other salts of the same type. On the addition of a chromate to this solution the much more difficultly soluble $PbCrO_4$ is precipitated, and is not dissolved by dilute acetic acid.

2. This confirmatory test is also applied to the $PbSO_4$ precipitate obtained in the analysis of the copper group (P. 26). In that case the precipitate may also contain bismuth, which would dissolve in ammonium acetate and give a yellow precipitate on the addition of K_2CrO_4; but this precipitate, unlike the $PbCrO_4$, dissolves readily in acetic acid.

Procedure 15. — Pour repeatedly through the filter containing the residue insoluble in hot water (P. 12) a 10–20 ccm. portion of NH_4OH

(0.96). (Black residue on the filter, presence of MERCUROUS MERCURY.) Acidify the filtrate with HNO_3. (White precipitate, presence of SILVER.)

Notes. — 1. The black residue produced by the action of NH_4OH on Hg_2Cl_2 is a mixture of finely divided mercury with the white mercuric compound $HgClNH_2$. The reaction is expressed by the equation:

$$Hg_2Cl_2 + 2NH_4OH = HgClNH_2 + Hg + NH_4Cl + 2H_2O.$$

The compound $HgClNH_2$ may be considered to be a derivative of $HgCl_2$, formed by replacing an equivalent of chlorine by the univalent radical NH_2.

2. It is to be noted that mercury will not be in the mercurous state, and therefore will not be precipitated with this group, if the substance has been heated with strong nitric acid or *aqua regia*.

3. AgCl dissolves readily in NH_4OH, owing to the formation of a soluble complex salt, $Ag(NH_3)_2Cl$, which in solution is largely dissociated into $Ag(NH_3)_2^+$ and Cl^- ions. This complex cathion has so slight a tendency to dissociate that in a normal solution of NH_4OH the ratio of its concentration to that of the simple Ag^+ ion is about 10^7.

4. HNO_3 reprecipitates the AgCl from its solution in NH_4OH, owing to the facts that the complex cathion is slightly dissociated according to the equation $Ag(NH_3)_2^+ = Ag^+ + 2NH_3$, and that the NH_3 combines with the added acid, forming NH_4NO_3, thus causing the complex cathion to dissociate further, until the Ag^+ concentration increases to such an extent as to make the product of it into the Cl^- concentration greater than the solubility product for AgCl.

5. The test is less delicate when the NH_4OH is neutralized with HCl, owing to the solubility of AgCl in strong chloride solutions, which arises, probably, from the formation of a salt with a complex anion, like $NH_4^+AgCl_2^-$.

Precipitation and Separation of the Copper and Tin Groups

Procedure 21. — Treat separately as follows the various acid solutions previously obtained (P. 11, 4, 2, 5, 6, 7, 8), each of which should contain 4 ccm. HCl (1.12) or 1.5 ccm. H_2SO_4 (1.84) and have a volume of about 40 ccm. Heat the solution in a conical flask nearly to boiling, and pass into it H_2S gas until it is saturated, and then for 10–15 minutes longer, keeping the solution at 70–90°. [*If the rarer elements are likely to be present, continue the precipitation in a pressure bottle as described in N. 3.] Cool the mixture; without filtering add to it 60 ccm. water, completely saturate it in the cold with H_2S gas, cork the

flask, shake it, and allow it to stand 15 minutes. Filter, and wash the precipitate with hot water. (Precipitate, P. 22; filtrate, P. 61.)

Notes. — 1. No sharp line can be drawn between the solubilities of the sulphides of the copper and tin groups and those of the iron group; they form rather a graded series in which the solubility of each member differs from that of the next only by a greater or less amount. Since now, owing to the effect of the added acid in reducing the ionization of the hydrogen sulphide, the solubility of any sulphide increases as the concentration of acid (or, more strictly, of hydrogen ion) in the solution increases, the line between precipitation and non-precipitation will fall at a point in the series dependent on the acid concentration and temperature. Thus, if arranged in the order in which they are precipitated from cold HCl solutions of decreasing concentration, the series is approximately as follows: arsenic, mercury and copper, antimony, bismuth and stannic tin, cadmium, lead and stannous tin, zinc, iron, nickel and cobalt, manganese. For reasons connected with the analysis of the separate groups, and for the reason that the separation is then a fairly sharp one, it has been found best to adjust the acid concentration so as to cause lead and stannous tin to precipitate and zinc to remain in solution.

2. The effect of acid on the precipitation of the various sulphides is explained by the Mass Action Law and Ionic Theory as follows: When a dilute solution, whether aqueous or acid, is saturated at a definite temperature with H_2S gas under the atmospheric (or any definite) pressure the H_2S as such always has the same concentration. This ionizes, however, to a slight extent into H^+ and HS^-, and to a still less extent into $2H^+$ and $S^=$. It is only the latter form of ionization that needs to be considered here. Now between the H_2S and its ions must be maintained the equilibrium expressed by the equation $(C_{H^+})^2 \times C_{S^=} = \text{const.} \times C_{H_2S}$; or, since in this case $C_{H_2S} = \text{const.}$, as just stated, it follows that also $(C_{H^+})^2 \times C_{S^=} = \text{const.}$ From this it is evident that when C_{H^+} is increased by the addition of acid to the solution, $C_{S^=}$ must be decreased in the proportion in which the square of C_{H^+} is increased; thus, if C_{H^+} is doubled, $C_{S^=}$ will be reduced to one-fourth. But in order that a sulphide — for example, of the formula $M^{++}S^=$ — may precipitate, the concentration product $C_{M^{++}} \times C_{S^=}$ must attain a value equal to the solubility product, which is the value of this concentration product which prevails in pure water in contact with the solid sulphide. The solubility product varies, however, with the nature of the sulphide and with the temperature; and therefore the acid concentration that will barely permit of precipitation when $C_{M^{++}}$ has

a definite value (for example, 1 mgm. in 100 ccm.) will be different for different sulphides and for the same sulphide at different temperatures. This acid concentration also varies with the nature of the acid, since the various acids are ionized to a different extent; thus zinc is precipitated from a fairly concentrated solution of acetic acid, since, owing to the slight ionization of this acid, the H^+ concentration is less than in a far more dilute solution of hydrochloric acid.

3. The solution is first saturated with H_2S at nearly the boiling temperature, because certain elements, especially arsenic in the higher state of oxidation (and the rarer elements, platinum and molybdenum), are only slowly and incompletely precipitated in the cold, and because the precipitates of almost all sulphides separate from hot solutions in a form better suited for filtration. In case precipitation seems to continue after the solution has become fully saturated with H_2S, it indicates that one of the elements just named may be present; and, to insure complete precipitation of the arsenic, the heating and passage of the gas must sometimes be continued for an hour longer. [*In case of molybdenum and the platinum elements, it is necessary, after most of the sulphide has separated, to cool the solution, to saturate it in the cold with H_2S in a stout bottle, to stopper the bottle with a cork securely held in place by wire, and to heat the bottle in a vessel of boiling water for an hour.] The solution is at first diluted to only about 40 ccm., because arsenic is more rapidly thrown out from rather strongly acid solutions, and because titanium would be precipitated as hydroxide if the solution were further diluted and were kept near the boiling temperature; moreover, bismuth and a moderate quantity of antimony do not precipitate as oxychloride at this dilution, but might do so if the solution were at once further diluted. The solution is finally diluted to 100 ccm., completely saturated in the cold, and allowed to stand, in order to cause the precipitation of even 1 mgm. of cadmium, lead, or stannous tin. Zinc, iron, nickel, and cobalt, on the other hand, do not precipitate at all under these conditions, even when 500 mgm. are present alone; and even 1 or 2 mgm. of any of them can be detected in the filtrate when large quantities of elements of the copper and tin groups are also present.

4. If at first a white or yellowish precipitate forms which immediately turns black with more H_2S, it indicates mercury. The white compound is $HgCl_2.2HgS$, and this is converted into HgS by the excess of H_2S. An orange precipitate separating from the hot, more concentrated solution shows antimony, or much cadmium (or selenium); a yellow one, arsenic or stannic tin. A yellow precipitate separating from the cold, more dilute solution shows cadmium. All the other sulphides are black

or brownish black. For the composition of the H_2S precipitates, see Table V. The quantity of sulphur combined with the metallic element, however, varies with the conditions of precipitation, owing to partial reduction, in the cases of arsen*ic* arsenic and antimonic antimony [*and of gold, selenium, tellurium, and probably molybdenum]. The extent to which the sulphides are combined with water and with hydrogen sulphide is also variable and in general unknown.

5. A white, finely divided precipitate of free sulphur will be formed if the solution contains substances capable of oxidizing H_2S. The most important of these likely to be present are ferric salts, chromates, [*vanadates], permanganates, and chlorates. Nitric acid, if moderately concentrated, would also destroy the H_2S; and for this reason it must have been removed as directed in P. 4. The reduction by H_2S of ferric salts to ferrous is attended by a change in color from yellow to colorless; of chromates to chromic salts, from orange to green; [*of vanadates to vanadyl salts, from yellow to blue]; and of permanganates to manganous salts, from purple to colorless.

Procedure 22. — Transfer the H_2S precipitate (P. 21) to a small casserole, add to it 10–25 ccm. ammonium monosulphide (if the original substance was treated with HNO_3 in P. 3), or 5–10 ccm. ammonium polysulphide (if it was dissolved in water alone), cover the dish, and warm the mixture slightly (to 40–60°) for about 10 minutes with frequent stirring. Add 10 ccm. water, filter, and wash once with hot water. [If the residue is considerable in amount and much has been extracted from it by this treatment, as indicated by its appearance, or as determined in P. 41, warm it again with ammonium monosulphide or polysulphide, and filter, collecting the filtrate separate from the first one.] Wash the residue thoroughly with hot water, to which, in case the precipitate tends to pass through the filter, about 5% solid NH_4NO_3 should be added. (Residue, P. 23; solutions, P. 41.)

Notes. — 1. In separating the copper and tin groups it is better to use (colorless) ammonium monosulphide rather than (yellow) polysulphide whenever the H_2S precipitate must contain any tin and most of any antimony present in the state of the higher sulphide (SnS_2 or Sb_2S_5). This is the case when hot concentrated nitric acid was used originally in dissolving the substance, but may not be so when water alone (or HCl) was used; hence the directions as to the choice between the two solvents. The polysulphide has the disadvantage that it dissolves a not inconsiderable quantity of CuS and HgS, thus making the tests for copper and mercury less delicate, and making it more difficult

to determine from the color of the HCl precipitate obtained from the ammonium sulphide solution in P. 41 whether or not elements of the tin group are present. The polysulphide must, nevertheless, be used if tin may be present as SnS, or much antimony as Sb_2S_3; for in the monosulphide SnS is almost insoluble and Sb_2S_3 is only moderately soluble (50–100 mgm. Sb in 10 ccm. of the reagent).

2. In order that the separation of the copper and tin groups by ammonium sulphide may be as complete as possible, it is necessary to employ a concentrated reagent highly charged with hydrogen sulphide, and containing, in the case of the polysulphide, an appropriate excess of sulphur. Suitable reagents are prepared by completely saturating a measured volume of NH_4OH of specific gravity 0.90 with H_2S in the cold, adding a fresh portion of NH_4OH (0.90) equal to two-thirds of the original volume, and diluting the mixture with an equal volume of water. From this solution, which constitutes "ammonium monosulphide," the "ammonium polysulphide" is prepared by dissolving in 1 liter of it 25 grams of flowers of sulphur. These reagents, especially the monosulphide, should be kept as far as possible out of contact with the air, which is conveniently done by storing them in small, completely filled, glass-stoppered bottles; for the oxygen of the air destroys the sulphide with liberation of sulphur, which at first combines with the still unchanged sulphide, but precipitates later when the oxidation becomes more complete. The monosulphide reagent is a solution of $(NH_4)_2S$ and of the products of its hydrolysis, NH_4SH, NH_4OH, and a little H_2S. The polysulphide contains in addition various polysulphides of the forms $(NH_4)_2S_{2-5}$ and $(NH_4)HS_{2-5}$ in unknown proportions.

3. The action of ammonium sulphide in dissolving the sulphides of the tin group depends on the formation of soluble salts of sulphoacids with complex anions. When the monosulphide is used, the reactions are as follows:

$$\left\{\begin{matrix}As_2S_3\\Sb_2S_3\end{matrix}\right\} + 3(NH_4)_2S = 2\left\{\begin{matrix}(NH_4^+)_3AsS_3^{\equiv}\\(NH_4^+)_3SbS_3^{\equiv}\end{matrix}\right\}$$

$$\left\{\begin{matrix}As_2S_5\\Sb_2S_5\end{matrix}\right\} + 3(NH_4)_2S = 2\left\{\begin{matrix}(NH_4^+)_3AsS_4^{\equiv}\\(NH_4^+)_3SbS_4^{\equiv}\end{matrix}\right\}$$

$$SnS_2 + (NH_4)_2S = (NH_4^+)_2SnS_3^{=}.$$

The excess of sulphur in the polysulphide oxidizes the lower sulphides (As_2S_3, Sb_2S_3, SnS) to the same sulphosalts as are obtained by dissolving the higher sulphides (As_2S_5, Sb_2S_5, SnS_2) in ammonium monosulphide. It will be seen that these sulphosalts are analogous to the salts of the familiar oxygen acids of these elements, the difference being that sulphur has replaced oxygen. *Analogous sulphosalts are formed with plati-

num, gold, and molybdenum, such as $(NH_4)_2PtS_3$, $(NH_4)_3AuS_3$, and $(NH_4)_2MoS_4$. Tellurium and selenium probably form similar compounds; but they may also combine directly with the ammonium sulphide in the same way as sulphur does, forming such compounds as $(NH_4)_2SSe_x$.

4. When ammonium monosulphide is used, 500 mgm. of any of the common tin-group elements, in the form of higher sulphide, dissolve in 25 ccm. of the reagent, provided this has been prepared as described in N. 2. When the polysulphide is used, 500 mgm. of any of the common tin-group elements, whether present as the higher or lower sulphide, dissolve in 10 ccm. of the reagent. The quantity of SnS and Sb_2S_3 dissolved by the polysulphide increases with its concentration and the excess of sulphur which it contains. A reagent containing a greater excess of sulphur is not used, however, since this would dissolve more CuS and HgS.

*5. Of the rarer elements, gold and platinum divide themselves in the ammonium sulphide treatment between the solution and the residue in a proportion which depends in large measure on the other elements which are present with them. They may, therefore, be found mainly either with the copper or with the tin group, and should be tested for in the course of the analysis of each group. Molybdenum dissolves in moderate quantity in either ammonium monosulphide or polysulphide, but when a quantity as large as 50 mgm. is present much of it remains with the copper group; yet there is no danger of not finding a considerable part of it in the tin-group solution, and its presence in the copper-group residue does not interfere with the detection of any of the elements, since it is not precipitated by any of the reagents used. When molybdenum is present, even in as small a quantity as 1 mgm., the ammonium sulphide solution has an orange-red color; and this becomes very deep when a moderate quantity is present. Selenium and tellurium pass completely, or almost completely, into the ammonium sulphide solution.

6. Even when a quantity of only 1 or 2 mgm. of arsenic or antimony is present with a large quantity (even 500 mgm.) of an element of the copper group, enough is extracted by either the monosulphide or polysulphide to be detected in the subsequent tests. With tin, however, the separation is imperfect; for, when a large quantity of elements of the copper group and only 3–5 mgm. of tin are present, the whole of this may remain undissolved; indeed, when much cadmium is present and the tin is in the stannous state, as much as 15 mgm. of the latter may be wholly left in the residue, even when the polysulphide is used. On this account it is necessary to test for tin in the course of the analysis of the copper group.

7. Of the sulphides of the copper group none dissolve to a significant extent in the monosulphide. Considerable CuS (5–10 mgm.) and a little HgS (0.5–1.0 mgm.) may, however, dissolve in the polysulphide when the substance contains a large quantity of these elements. Yet when 2 mgm. of either of these elements are present it can be detected in the analysis of the copper group, even when the polysulphide is used, provided only one treatment with it has been made.

8. Some sulphides, especially CdS, upon washing pass through the filter in the colloidal condition; the addition of a salt, such as NH_4NO_3, prevents this by coagulating the colloidal particles.

Analysis of the Copper Group

Procedure 23. — To the residue from the ammonium sulphide treatment (P. 22) in a casserole add 10–20 ccm. of a mixture of one volume HNO_3 (1.20) and two volumes water, heat to boiling, and boil gently for a minute or two. (Black residue, possible presence of MERCURY.) Filter and wash. (Residue, P. 24; solution, P. 26.)

Notes. — 1. Boiling HNO_3 of this concentration dissolves the sulphides of lead, bismuth, copper, and cadmium almost immediately, and is therefore preferable to a more dilute acid, with which the reaction would require for its completion several minutes' boiling. Scarcely any HgS is dissolved by the above treatment, unless the boiling is long continued.

2. Moderately concentrated HNO_3 dissolves sulphides much more rapidly than HCl or H_2SO_4 of the same concentration; for with the latter acids the sulphide ion is removed from the solution only by combination with the hydrogen ion forming slightly ionized H_2S and by the volatilization of the latter, while with HNO_3 the sulphide ion (or the H_2S in equilibrium with it) may also be destroyed by oxidation to ordinary sulphur. The oxidizing effect of HNO_3 is, however, considerable only when it is hot and moderately concentrated.

3. That HgS, unlike the other sulphides, does not dissolve in the dilute HNO_3 is doubtless due to the much smaller concentration of its ions in its saturated solution and to the fact that at this small concentration the sulphide ion (or the H_2S in equilibrium with it at a correspondingly small concentration) is oxidized only very slowly by the dilute HNO_3. HgS is, however, readily dissolved by more vigorous oxidizing agents, such as *aqua regia* or bromine water, since they react rapidly with sulphide ion (or with H_2S) even when its concentration is very small.

4. If more concentrated HNO_3 be used, or if the acid become concentrated by long boiling, the black HgS is dissolved in part, and the remainder is converted into a heavy, white, difficultly soluble compound ($Hg(NO_3)_2.2HgS$).

5. When much lead, copper, or bismuth is present the sulphur formed will generally enclose enough of the undissolved sulphide to give it a black color. [*Moreover, PtS_2 and Au or Au_2S if present are not dissolved by the HNO_3.] A black residue is therefore not necessarily HgS and must be further tested for mercury as described in P. 24.

6. Some sulphur is always oxidized to H_2SO_4 by the boiling HNO_3, but, even in the presence of much lead, $PbSO_4$ is not precipitated, owing to its moderate solubility in HNO_3.

7. Any SnS or SnS_2 not extracted by the ammonium sulphide treatment will be converted by HNO_3 into metastannic acid, most of which remains undissolved. Therefore, even a light-colored residue must be carefully collected if tin is to be tested for in this group.

Procedure 24. — Transfer the residue undissolved by HNO_3 (P. 23), with the filter if necessary, to a casserole, add 10–40 ccm. saturated Br_2 solution, cover the dish, and warm slightly for 5–10 minutes, with frequent stirring. Boil the mixture until the bromine is expelled, and filter. (Residue, P. 25.) [*If the solution is yellow, indicating that gold or platinum may be present, treat it by *P. 24*a*, and then proceed as follows.] Cool the solution, and add to it a few drops of HCl (1.12) and a 2% $SnCl_2$ solution, at first drop by drop; then add several cubic centimeters of a 10% $SnCl_2$ solution. (White precipitate turning gray, or gray precipitate, presence of MERCURY.) (Residue and solution, reject.)

Notes. — 1. Bromine water dissolves the sulphides of mercury, platinum, and gold, but leaves in the residue any metastannic acid. In case tin need not be tested for at this point, the residue may be more quickly dissolved by warming it with HCl (1.12) and adding gradually a little solid $KClO_3$; since metastannic acid is soluble in HCl, this then passes into solution with the mercuric salt.

2. In the final test for mercury HCl is added to prevent the precipitation of a basic tin salt when the $SnCl_2$ reagent is diluted, and to cause the formation at first of white Hg_2Br_2 or Hg_2Cl_2. For the latter reason, also, dilute $SnCl_2$ solution is added drop by drop to the cold solution. By the excess of $SnCl_2$ the white precipitate is reduced to gray, finely divided mercury.

3. The presence of mercury at this point does not show that it was originally in the mercuric state, except in case the substance was dissolved without the use of hot or concentrated HNO_3. If it is desired to determine in which state the mercury was originally present, a solution of the substance in water, in dilute H_2SO_4, or in cold, very dilute HNO_3 must be prepared and analyzed for mercurous and mercuric mercury by the regular process, beginning with P. 11.

*4. Platinum and gold compounds, if not removed, are reduced by $SnCl_2$, the former giving a reddish brown solution and the latter a dark-colored or purple precipitate of metallic gold. The presence of these elements would thus interfere with, or prevent the detection of, mercury, and it is therefore directed to remove them.

***Procedure 24a.** — To the solution of the sulphides in bromine water (P. 24) add about 0.5 gram solid KCl and 1–2 ccm. HCl (1.12), evaporate until KCl crystallizes out, cool, and add water drop by drop until almost all the KCl has dissolved. (Yellow precipitate, presence of PLATINUM.) Filter and wash with a little saturated KCl solution. Confirm the presence of platinum in the precipitate by *P. 43*a*. To the filtrate add 10% NaOH solution till alkaline, and then about 1 ccm. more. Then add saturated oxalic acid ($H_2C_2O_4$) solution until the solution becomes distinctly acid, dilute to about 15 ccm., and digest on a steam bath for 10–15 minutes. (Purplish black or dark yellow precipitate, presence of GOLD.) Filter. Reject the precipitate. Test the filtrate for mercury with $SnCl_2$ solution by the last part of P. 24.

Note. — 1. For notes upon this process, see under *P. 43*a* and 43*b*. By means of it can be detected 1 mgm. of gold or platinum in the presence of much mercury (at least 200 mgm.), or 1 mgm. of mercury in the presence of much gold or platinum.

Procedure 25. — If it is necessary to extract tin (see N. 1 below) from the residue undissolved by HNO_3 and bromine water (P. 24), digest it, if it is still dark-colored, with another portion of bromine water to extract the rest of the mercury, filter, reject the filtrate, and warm the residue slightly with 2–5 ccm. ammonium monosulphide, filter, and unite the solution with the main ammonium sulphide solution obtained in P. 22.

Note. — 1. If it is desired to detect with certainty the presence in the substance of a quantity of tin smaller than 5 mgm., and if elements of the copper group are present in large quantity (100–500 mgm.), it

is necessary to recover the tin that remained with the copper group; for, as stated in P. 22, N. 5, a quantity of tin as large as 5 mgm. (or even larger when stannous tin and cadmium are both present) may remain entirely in the residue undissolved by ammonium sulphide when this residue is large. By extracting the tin as described in this procedure and uniting it with the main solution of the tin group 2 mgm. of tin can be detected.

Procedure 26. — To the HNO_3 solution (P. 23) add 2–3 ccm. concentrated H_2SO_4, and evaporate in a casserole until fumes of H_2SO_4 begin to come off. Cool and pour into 10–15 ccm. cold water, rinsing out the casserole with the same solution. Cool again, shake, and allow the mixture to stand 5 minutes, but not much longer. (Finely divided white precipitate, presence of LEAD; but a coarsely crystalline precipitate may be due to bismuth.) Filter and wash the precipitate with H_2SO_4 (1.20), and finally with a little water. (Precipitate, P. 14, to confirm the presence of lead; filtrate, P. 27.)

Notes. — 1. $PbSO_4$ is somewhat soluble both in water and in concentrated H_2SO_4, but much less so in moderately dilute H_2SO_4, its solubility being scarcely appreciable in mixtures containing one volume of H_2SO_4 (1.84) and two to six volumes of water. That the solubility in dilute H_2SO_4 is less than that in water is due mainly to the common-ion effect. Concentrated H_2SO_4 is, of course, an entirely different solvent. $PbSO_4$ dissolves fairly readily in dilute HNO_3 (or in dilute HCl), owing to metathesis arising mainly from the tendency to form un-ionized H_2SO_4; hence, although this effect of HNO_3 is partly counteracted by the presence of much H_2SO_4, yet, to ensure complete precipitation of $PbSO_4$, the HNO_3 must be removed by evaporation.

2. When much bismuth is present it ordinarily is dissolved at first when the water is added to the concentrated H_2SO_4, provided the mixture is kept cold; but from this solution a coarsely crystalline precipitate of an oxysulphate, such as $(BiO)_2SO_4$, separates slowly upon standing in the cold but almost immediately upon heating, and to such an extent that there may remain in solution not more than 50 mgm. of bismuth. If such a precipitate has separated with the $PbSO_4$, filter, treat the filtrate by P. 27, and dissolve the precipitate by pouring repeatedly through the filter a 5–10 ccm. portion of HCl (1.12), and test the solution so obtained for lead by following P. 26 and P. 14.

Procedure 27. — To the H_2SO_4 solution (P. 26) add NH_4OH slowly until a strong odor of it persists after shaking. (White precipi-

tate, possible presence of BISMUTH; blue solution, presence of COPPER.) Shake to cause coagulation, filter, and wash the precipitate. (Precipitate, P. 28; filtrate, P. 29 and 30.)

Notes. — 1. The precipitate produced by NH_4OH may also consist of $Fe(OH)_3$, or of other hydroxides of the iron group, if these elements were carried down in the H_2S precipitate or were not completely removed from it by washing. The formation of a small precipitate is, therefore, not a sufficient proof of the presence of bismuth, and the confirmatory tests must be applied. Antimony which, like bismuth, gives with water a precipitate of an oxychloride cannot be present in sufficient quantity to be precipitated by NH_4OH.

2. That $Cd(OH)_2$ or $Cu(OH)_2$, though only very slightly soluble in water, dissolves in NH_4OH is due to the conversion of the Cd^{++} or Cu^{++} ion in the saturated solutions into the complex cathion $Cd(NH_3)_4^{++}$ or $Cu(NH_3)_4^{++}$, which is formed by combination of the simple ion with un-ionized ammonia. These complex cathions have an extremely small ionization tendency; thus for cadmium in a normal NH_4OH solution the ratio of the concentration of the complex to the simple ion is about 10^7. The solubility of these hydroxides in NH_4OH is greatly increased by the presence of ammonium salts, since these salts, owing to the common-ion effect, greatly reduce the ionization of the NH_4OH, and therefore the OH^- concentration in the solution, thus enabling the Cd^{++} or Cu^{++} concentration, and therefore also the corresponding complex ion concentration, to attain a much larger value than in the saturated solutions of $Cd(OH)_2$ or $Cu(OH)_2$ in NH_4OH alone. It will be noticed that four distinct equilibria are involved — that between solid $Cd(OH)_2$ or $Cu(OH)_2$ and its ions; that between Cd^{++} or Cu^{++}, NH_3, and $Cd(NH_3)_2^{++}$ or $Cu(NH_3)_4^{++}$; that between NH_4OH, NH_3, and H_2O; and that between NH_4OH, NH_4^+, and OH^-. It may be further mentioned that, since in any dilute solution the concentration of the water is substantially constant, the concentration of any hydrate (like NH_4OH) is proportional to that of the anhydrous substance (NH_3).

Procedure 28. — Dissolve the NH_4OH precipitate (P. 27) by pouring a little HCl (1.12) through the filter, evaporate off the acid almost completely, leaving the residue only barely moist with it, add 1–2 ccm. water, pour the solution into a flask containing 100 ccm. water heated to 50–70°, and allow the mixture to stand 2 or 3 minutes. (White precipitate, presence of BISMUTH.) Filter, wash once, and pour through the filter a freshly prepared solution of sodium stannite. (Black residue, presence of BISMUTH.)

Notes. — 1. The white precipitate formed in the first confirmatory test for bismuth is BiOCl, which is produced by the hydrolysis of $BiCl_3$. If HCl, the other product of the hydrolysis, is present in the solution, the reaction will not be complete, and a greater or less quantity of bismuth will remain in solution and thus escape detection. This quantity increases rapidly with the acid concentration in accordance with the Law of Mass-Action. For this reason, if the presence of half a milligram of bismuth in the precipitate is to be detected, the HCl must be removed by evaporation so completely that not more than 0.2 ccm. remain, and the solution must be added to a large volume of water. Warm water is used, because the precipitation of BiOCl takes place more rapidly at the higher temperature.

2. The solution of sodium stannite (Na_2SnO_2) is prepared when needed by adding a 10% NaOH solution to a 10% $SnCl_2$ solution until the $Sn(OH)_2$ first formed is dissolved. The solution must be freshly prepared, because it decomposes spontaneously into sodium stannate (Na_2SnO_3) and metallic tin, and because it oxidizes in contact with air to sodium stannate. SnO_2H_2 is an example of a so-called amphoteric substance — one which acts either as a base or an acid, as is shown by its solubility in both acids and alkalies.

3. The final test with sodium stannite depends on the reduction of BiOCl to black metallic bismuth. The test is an extremely delicate one, and by it may be detected a quantity of bismuth so small as to produce only a scarcely visible turbidity of BiOCl; for, when the precipitate in such a solution is collected on a filter and treated with stannite, the black color of the bismuth is very apparent. Antimony oxychloride, even if present, is not blackened by the stannite. The NH_4OH precipitate itself might be directly tested with this reagent; for the other reducible substances, like $Fe(OH)_3$, $Pb(OH)_2$, or $Cu(OH)_2$, that might possibly be present in that precipitate are not reduced by short contact with stannite solution in the cold. It is, however, often desirable to get the double indication of the presence of bismuth, as furnished by the precipitation of the oxychloride by water and by its blackening with the sodium stannite.

Procedure 29. — Acidify one-fourth of the NH_4OH solution (P. 27) with acetic acid, add 2–3 drops 3% $K_4Fe(CN)_6$ solution, and allow the mixture to stand for several minutes. (Red precipitate, presence of COPPER.) If it is uncertain whether there is a precipitate, pour the solution through a filter and wash with a little water. (Pink color on the filter, presence of COPPER.)

Notes. — 1. The confirmatory test for copper depends on the precipitation of red cupric ferrocyanide, $Cu_2Fe(CN)_6$. Since this test is a more delicate one than the formation of a blue color with NH_4OH (P. 27), it should be tried even when the NH_4OH solution is colorless. Cadmium is also precipitated by $K_4Fe(CN)_6$; but the precipitate is white, and does not prevent the pink color of the copper compound from being detected, provided only a small quantity of $K_4Fe(CN)_6$ is added; for the copper salt, owing to its smaller solubility, is first precipitated.

2. Nickel, like copper, gives a blue solution with excess of NH_4OH; but even if present it would give a greenish white, not a red precipitate, with $K_4Fe(CN)_6$. Aside from copper, only the rarer elements uranium and molybdenum give red precipitates with this reagent; but they do not do so in an acetic acid solution, such as is obtained in the procedure.

Procedure 30. — To the remainder of the NH_4OH solution (P. 27 and 29) add solid KCN till the blue color disappears, and pass in H_2S gas for about half a minute. (Flocculent yellow precipitate, presence of CADMIUM.) (Precipitate and solution, reject.)

Notes. — 1. By the addition of KCN the copper salt is reduced from the cupric to the cuprous state and then combines with the excess of KCN to form the complex salt $K^+Cu(CN)_2^-$ (potassium cuprocyanide). This result is due to the fact that cupric cyanide tends to decompose spontaneously into cuprous cyanide and cyanogen, and that this reaction takes place completely in KCN solution, owing to removal of the cuprous cyanide by combination with the excess of KCN. In the presence of NH_4OH the cyanogen is not evolved as a gas, but reacts with it, forming cyanate (NH_4CNO) and cyanide and other more complex products. The fact that neither CuS nor Cu_2S is precipitated from this solution by an alkaline sulphide shows that neither the Cu^{++} nor Cu^+ concentration is sufficient to cause the value of the solubility product to be attained. The extremely small Cu^+ concentration is due to the very slight ionization tendency of the complex anion $Cu(CN)_2^-$: thus it has been estimated that in a normal KCN solution the ratio of the concentration of the complex anion to that of the simple Cu^+ ion is about 10^{26}.

2. The cadmium ammonia salt is also converted by KCN into a complex cyanide, namely, $K^+_2Cd(CN)_4^=$ (potassium cadmicyanide), since its complex anion has a much smaller ionization tendency than the cathion $Cd(NH_3)_4^{++}$; thus in a normal KCN solution the ratio of the concentration of the complex anion to that of the simple Cd^{++} ion is

about 10^{17}. Yet this complex anion is sufficiently dissociated into Cd^{++} ion to cause the solution to become saturated with CdS when an alkaline sulphide is added.

3. A very small black precipitate (which may be due to HgS or PbS) may sometimes be produced in the final test for cadmium with H_2S; but, provided the analysis has been properly conducted, not in sufficient quantity to prevent the yellow color of 1 or 2 mgm. of CdS from being seen. In case a black precipitate is produced, and thus prevents a positive conclusion as to the entire absence of cadmium, the precipitate may be treated, in order to eliminate the black sulphide, as follows: Boil the precipitate for about 5 minutes with about 15 ccm. of a mixture of one volume of H_2SO_4 (1.20) with four volumes of water, filter, cool the filtrate, add to it three times its volume of water, and pass H_2S into it for 5–10 minutes. A yellow precipitate of CdS should then be obtained, if cadmium is present.

Analysis of the Tin Group

Procedure 41. — Dilute in a small flask the first portion of the ammonium sulphide solution (P. 22) with about 20 ccm. water, make it distinctly acid with HCl, and warm it slightly for 5 minutes with frequent shaking to coagulate the precipitate. (Fine, not flocculent, white or pale yellow precipitate, absence of TIN GROUP; deep yellow or orange flocculent precipitate, presence of TIN GROUP.) Treat the second portion of the ammonium sulphide solution (P. 22) in the same way, and unite the precipitate, if considerable in amount, with the first one. Filter out and wash the precipitate, using suction, finally sucking it as dry as possible. (Precipitate, P. 42; filtrates, reject.)

Notes. — 1. Much time is saved by determining at this point whether or not any element of the tin group is present. When ammonium monosulphide has been used, there is usually no difficulty in drawing a definite conclusion in regard to this from the size and appearance of the HCl precipitate; for in the absence of the tin group only a very small, nearly white precipitate of finely divided sulphur separates. When, however, ammonium polysulphide has been used, it may not be possible to decide as to the presence or absence of a small quantity (1–5 mgm.) of arsenic, antimony, or tin; for not only is a fairly large precipitate of sulphur then obtained, but it may be darkened in color by the presence of CuS or HgS: yet when the precipitate is nearly white, and finely divided or granular, the conclusion can be drawn at once that no element of the tin group is present in quantity as large as 1 mgm.; and when it has

a pronounced yellow color (indicating arsenic or tin) or an orange-red color (indicating antimony) the conclusion can be drawn that one of these elements is present. In this connection it may be mentioned that a mixture of SnS_2 and Sb_2S_5 does not always have a color intermediate between those just mentioned, but may be brown or dark gray.

2. When, however, the HCl precipitate from a polysulphide solution is fairly small and is dark brown (indicating copper) or dark gray or black (indicating mercury or one of the rarer elements) or of unpronounced yellow or orange color, so as to make any conclusion as to the tin group doubtful, the precipitate is best treated as follows: Heat it with 15–20 ccm. NH_4OH (0.96) almost to boiling for 5 minutes and filter; test the precipitate for copper by P. 23, 28, and 30 if it has not already been found present; add to the filtrate a few drops of ammonium monosulphide, filter out any precipitate, heat the filtrate to boiling, make it acid with HCl, shake, filter out the precipitate, and treat it by P. 42 as usual. The character of the HCl precipitate thus obtained will clearly indicate the presence or absence of the tin group; for by the treatment with NH_4OH the excess of sulphur originally present and any CuS is left undissolved, and by the $(NH_4)_2S$ added to the solution any mercury present is precipitated, so that the HCl precipitate can contain only sulphides of the tin group and a very little sulphur. As_2S_5, Sb_2S_5, and SnS_2 all dissolve in NH_4OH (though in the cases of Sb_2S_5 and SnS_2 less abundantly than in ammonium sulphide), owing to the formation of a mixture of salts of the intermediate sulphoacids, such as H_3AsO_3S and $H_3AsO_2S_2$. The addition of $(NH_4)_2S$ to the NH_4OH solution and the heating serve to convert these into more highly sulphurated acids, from which HCl will then precipitate the simple sulphides completely. — The incidental removal of the small amounts of CuS and HgS by the NH_4OH treatment is not necessary as far as the analysis of the tin group is concerned, since their presence does not interfere with the detection of even 1 mgm. of arsenic, antimony, or tin; but it does enable 1 or 2 mgm. of copper to be detected which might otherwise be lost.

3. When the HCl is added to the solution of the sulphosalts, the corresponding sulphoacids which are liberated decompose immediately into H_2S and the solid sulphides, which are now necessarily in the higher state of oxidation, since the lower sulphides, if originally present, have been oxidized by the polysulphide. The fact that the sulphoacids decompose while the sulphosalts are stable is a consequence of the Mass-Action Law, which, when applied to the dissociation of the complex anions taking place according to the equations,

$SnS_3^{=} = SnS_2 + S^{=}$, $2AsS_4^{\equiv} = As_2S_5 + 3S^{=}$, $2SbS_4^{\equiv} = Sb_2S_5 + 3S^{=}$,

evidently requires that these decompose to a greater extent into the un-ionized sulphides (SnS_2, etc.) the smaller the concentration of the $S^=$ ion in the solution. Now in the solution of the largely ionized $(NH_4^+)_2S^=$ there is a fairly large concentration of $S^=$ ion; but when the solution is made acid with HCl, the $S^=$ ion is, for the most part, converted by the relatively large concentration of the H^+ ion into the slightly ionized substances HS^- and H_2S; and consequently the concentration of the un-ionized sulphides in the solution becomes great enough to exceed the solubility value, and the solid sulphides separate out.

Procedure 42. — Transfer the precipitated sulphides dried by suction (P. 41) to a wide test tube, add from a small graduate exactly 10 ccm. HCl (1.20), and heat nearly but not quite to boiling (preferably by immersing the test tube in hot water or on a steam bath) for about 10 minutes with frequent stirring. Add 5 ccm. water from a graduate containing 40 ccm. water, filter, wash once with about 5 ccm. water from the graduate, collecting this wash water with the filtrate; remove the filtrate, and add to it the water remaining in the graduate; wash the residue with HCl (1.12). (Residue, P. 43; filtrate, P. 45.)

Notes. — 1. If a much weaker HCl solution than the acid of specific gravity 1.20 is used, or if the acid becomes diluted by an unnecessary quantity of water left in the precipitate, much Sb_2S_5 will be left undissolved. Even with the strong acid some Sb_2S_5 may remain undissolved, especially when a large quantity is present, in which case the residue if small in amount will have an orange color. This small quantity of Sb_2S_5 would be only very slowly removed by further treatments with HCl; it does not, however, interfere with the subsequent tests for arsenic. Moreover, when only a small quantity of Sb_2S_5 is originally present, a large proportion of it is extracted, so that it will not escape detection. Sb_2S_5 dissolves with formation of $SbCl_3$ and liberation of sulphur: SnS_2 with formation of $SnCl_4$.

2. If the solution be kept just below the boiling point during the treatment with HCl, the amount of As_2S_5 which dissolves in 10 minutes is insignificant; but this is no longer true if the solution be allowed to boil, for the boiling rapidly expels from the solution the H_2S liberated from the other sulphides or by slight decomposition of the As_2S_5 itself, and thus enables the decomposition of the latter to proceed further.

3. As_2S_3 is more rapidly dissolved by HCl than is As_2S_5. If the former can be present in the precipitate, which can occur only when HNO_3 or *aqua regia* was not used in dissolving the original substance

and if ammonium monosulphide was employed for separating the copper and tin groups, the procedure should be modified as follows: After the addition of HCl to the sulphides saturate with H_2S in the cold, and then heat nearly but not quite to boiling for 10 minutes, passing a slow current of H_2S gas through the mixture. Under these conditions scarcely any As_2S_3 dissolves.

4. About 5 ccm. water are added to the HCl solution to enable it to be filtered. If more be added, and the H_2S has not been completely expelled from the solution, a precipitate of Sb_2S_3 may separate. If this happens after the filtration, it does, of course, no harm.

5. Care must be taken to follow closely the directions in regard to the quantities of HCl and water used; for the subsequent separation of antimony and tin (P. 45) depends upon a proper concentration of the acid.

6. The greater part of any CuS and HgS present will be dissolved by the HCl, and will be precipitated later with the Sb_2S_3 (P. 45). A little remains with the As_2S_5, but this does not interfere with the tests for arsenic. *Of the precipitates of the rarer elements, PtS_2, $Au_2S_{3\text{-}6}$, Se, and MoS_3 are dissolved by the HCl scarcely at all, and TeS_2 only to a small extent. The dissolving of the last, like that of As_2S_3, can be entirely prevented by passing a slow current of H_2S through the hot HCl solution.

Procedure 43. — Warm the residue from the HCl treatment (P. 42) with 5–10 ccm. HCl (1.12), adding solid $KClO_3$ in small portions until the reaction is complete; filter off the sulphur, and evaporate the solution to about 2 ccm. [If the solution is still distinctly yellow, or if a yellow precipitate has separated, test for and remove platinum by *P. 43*a*, and treat the filtrate as follows.] Add NH_4OH gradually until the solution after shaking smells of it; cool, filter off and reject any precipitate. Add to the filtrate about one-third its volume of NH_4OH (0.90) and several drops of magnesium ammonium chloride reagent, and shake. If no precipitate appears, rub the walls of the test tube gently with a glass rod for a minute or two. (White crystalline precipitate, presence of ARSENIC.) Collect the precipitate on a filter and wash it once with NH_4OH (0.96). (Precipitate, P. 44; filtrate reject, or test for gold, selenium, tellurium, and molybdenum, by *P. 43*b*).

Notes. — 1. The main reaction between $KClO_3$ and concentrated HCl is the formation of Cl_2; the yellow color results from the formation of a small proportion of chlorine dioxide, ClO_2.

2. As_2S_5, though only very slowly dissolved by HCl alone, is dissolved rapidly by it in the presence of Cl_2, because of the destruction of the H_2S, one of the reaction products, by oxidation. It is dissolved with formation of H_3AsO_4; $AsCl_5$ has never been shown to exist. When, as here, arsenic is present in the higher state of oxidation, solutions of it may be boiled without loss of an amount of arsenic significant in qualitative analysis.

3. A white precipitate, obtained on adding NH_4OH, may arise from the presence of mercury. The NH_4OH solution may contain not only arsenic, but also certain rare metals and the small quantities of copper (if ammonium polysulphide was used), antimony, and stannic tin that were not dissolved out of the sulphide precipitate by HCl.

4. The test for arsenic depends on the formation of magnesium ammonium arsenate, $Mg^{++}(NH_4)^+AsO_4^{=}$. This salt is somewhat soluble in water, and therefore the solution tested should be fairly concentrated. Owing to hydrolysis (into NH_4OH and $Mg^{++}HAsO_4^{=}$), the precipitate is much more soluble in water than in a strong NH_4OH solution; hence the addition of a large quantity of the latter. Like other crystalline precipitates, it tends to form a supersaturated solution. Precipitation is promoted by agitation, by rubbing the walls of the tube with a glass rod, and by increasing the degree of supersaturation, which is done by concentrating and adding NH_4OH. Provided these precautions are taken and the total volume of the final solution does not exceed 5 ccm., the presence of even half a milligram of arsenic can be detected. Care must be taken not to scratch the glass by violent rubbing, since the powdered glass may be mistaken for the $MgNH_4AsO_4$ precipitate.

5. The magnesium ammonium chloride reagent contains $MgCl_2$ and NH_4Cl. The presence of the latter salt prevents the precipitation of $Mg(OH)_2$ by NH_4OH, by reducing the OH^- concentration.

Procedure 43a. — Evaporate the solution of the sulphides in HCl and $KClO_3$ (P. 43) until KCl crystallizes out, cool, and add water drop by drop until the KCl just redissolves. (Yellow precipitate, presence of PLATINUM.) Filter, wash the precipitate with a little cold saturated KCl solution, and treat the filtrate by P. 43 to detect and remove arsenic. Dissolve the precipitate by pouring repeatedly a 5–10 ccm. portion of hot water through the filter, and add to the solution a few drops of KI solution. (Deep red color, presence of PLATINUM.)

Notes. — 1. Potassium chlorplatinate, $K^+_2PtCl_6^{=}$, is fairly soluble in water, but much less so in a saturated KCl solution, owing to the common-ion effect.

2. The deep red color formed on the addition of KI to K_2PtCl_6 is due to the formation of K_2PtI_6 in solution. When the K_2PtCl_6 is present in excess a black precipitate of PtI_4 separates, but this dissolves readily on further addition of KI.

***Procedure 43b.** — To the filtrate from the $MgCl_2$ precipitate (P. 43) add 2–3 ccm. saturated oxalic acid ($H_2C_2O_4$) solution, and evaporate in a casserole to 3–4 ccm. to expel the excess of ammonia. Make the solution slightly acid with $H_2C_2O_4$, if it is not already so, add about 10 ccm. water, and digest on a steam bath for several minutes. (Purple precipitate, presence of GOLD.) To the mixture add 2–3 ccm. HCl (1.12) to dissolve any tellurium hydroxide, and filter. (Precipitate, reject; filtrate, *P. 43*c*.)

Notes. — 1. Metallic gold is precipitated readily from a solution of ammonium oxalate only when the solution is hot and slightly acid; but even under these conditions the precipitation is complete only after several minutes. If these conditions are not realized, several milligrams of gold may escape detection.

2. The more powerful reducing agents, H_2SO_3 and $SnCl_2$, also precipitate gold, but they reduce selenium and tellurium (and mercury) compounds as well.

***Procedure 43c.** — Evaporate the filtrate from the $H_2C_2O_4$ precipitate (*P. 43*b*) almost to dryness, add 10 ccm. HCl (1.12), and filter off any KCl that has separated. Collect the filtrate in a test tube, add about 0.2 gram solid Na_2SO_3, and allow the mixture to stand for at least 5 minutes, adding more Na_2SO_3 if the SO_2 odor disappears. (Red precipitate, presence of SELENIUM.) Filter. (Precipitate, reject; filtrate, *P. 43*d*.)

Notes. — 1. By the action of H_2SO_3 on selenous acid (H_2SeO_3) in the cold a voluminous red precipitate of selenium is quickly formed; but the reaction is complete only after several minutes. When the solution is hot the more compact black modification of selenium is obtained; but the test is then less delicate and less characteristic.

2. Tellurium is reduced by H_2SO_3 in moderately dilute HCl solutions, but not at all when the concentration of the acid is as great as that of specific gravity 1.12. Selenium, however, separates completely from a more concentrated acid, as well as from a more dilute one. For these reasons, though a greater concentration of HCl is unobjectionable, a lesser concentration would cause the precipitation of tellurium and obscure the selenium test.

*Procedure 43d. — Dilute the filtrate from the H_2SO_3 precipitate (P. 43*c*) with an equal volume of water, and add a few drops of KI solution and a little solid Na_2SO_3. (Black precipitate, presence of TELLURIUM.) Filter after a few minutes. (Precipitate, reject; filtrate, *P. 43*e*.)

Notes. — 1. As stated in *P. 43*c*, N. 2, tellurium is precipitated by H_2SO_3 alone when the HCl solution of specific gravity 1.12 is diluted somewhat with water, especially if the mixture is kept hot. The precipitation, however, is much more rapid and is complete after a few minutes even in the cold if KI is also present. KI alone does not reduce tellurium compounds, but precipitates black TeI_4, which dissolves somewhat in excess of KI, forming a deep red solution of K_2TeI_6. The advantage of adding KI is that the iodine compound of tellurium is more rapidly reduced by H_2SO_3 than is the chlorine compound or tellurous acid itself.

2. Selenous acid is immediately reduced to selenium by KI in HCl solution; but this element is completely precipitated by H_2SO_3 in *P. 43*c* if the directions there given are followed; even if not so removed, it would give a red precipitate, not a black one.

3. Molybdic acid by this treatment is also slowly reduced to a lower compound, which remains in solution. Iodine may thereby be liberated and even precipitated after all the H_2SO_3 has been oxidized. For this reason the solution should not be allowed to stand for more than half an hour before filtering.

*Procedure 43e. — Boil the filtrate from the KI precipitate (*P. 43*d*) until the SO_2 is expelled, cool the solution, add 3 or 4 ccm. 10% KCNS solution and some granulated zinc. (Red color, presence of MOLYBDENUM.) [If it is desired to form a better estimate of the quantity of molybdenum present, treat the solution as described in N. 4.]

Notes. — 1. The H_2SO_3 is boiled out, since otherwise sulphur would be precipitated by the action of zinc.

2. The red color is due to the formation of $Mo(SCN)_4$, corresponding to MoO_2, an intermediate stage in the reduction of molybdic acid (H_2MoO_4) by the zinc. The color may appear before the addition of zinc, since the H_2MoO_4 may already have been partially reduced by H_2SO_3 and HI. Long-continued action of zinc causes the red color to disappear; for the chloride $MoCl_3$, corresponding to the oxide Mo_2O_3, to which H_2MoO_4 is finally reduced, gives a colorless solution with KCNS.

3. Ferric salts also give a red color with KCNS; but a coloration arising from the presence of iron as an impurity disappears almost immediately on the addition of zinc, owing to reduction to the ferrous state.

4. It is difficult from the depth of the red coloration to form an estimate of the quantity of molybdenum present. The molybdenum may be obtained in the form of a precipitated sulphide by treating the solution to which KCNS and zinc have been added as follows: Add a little solid $KClO_3$ and boil to reoxidize the molybdenum, and finally to expel the chlorine, adding more HCl (1.20), if necessary; pass H_2S into the solution for 10 minutes, keeping it near the boiling point.

Procedure 44. — Dissolve the $MgCl_2.NH_4Cl$ precipitate (P. 43) by pouring a little HCl (1.12) through the filter, heat the solution obtained nearly to boiling, and pass in H_2S for at least 5 minutes, keeping the solution hot. (White precipitate turning yellow, presence of ARSENIC.) (Precipitate and solution, reject.)

Notes. — 1. The slow formation in a dilute acid solution of a pale yellow precipitate with H_2S is a characteristic test for H_3AsO_4. The precipitate is a mixture of As_2S_5, As_2S_3, and sulphur, the amount of As_2S_5 being comparatively small in the presence of strong HCl and at high temperatures.

2. A considerable amount of H_2S may be absorbed by a dilute H_3AsO_4 solution before any precipitate appears. This is due to the formation of H_3AsO_3S, which then decomposes slowly, giving H_3AsO_3 and sulphur. This last decomposition may be accelerated by increasing the H^+ concentration and by raising the temperature. The H_3AsO_3 formed reacts at once with H_2S, and As_2S_3 is precipitated. The reactions taking place are, therefore,

$$H_3AsO_4 + H_2S = H_3AsO_3S + H_2O,$$
$$H_3AsO_3S = H_3AsO_3 + S,$$
$$2H_3AsO_3 + 3H_2S = As_2S_3 + 6H_2O,$$

which together give the reaction,

$$2H_3AsO_4 + 5H_2S = As_2S_3 + S_2 + 8H_2O.$$

The rate of this reaction depends upon the rate of the slowest of the single reactions — the decomposition of H_3AsO_3S. As_2S_5 is produced by an independent reaction,

$$2H_3AsO_4 + 5H_2S = As_2S_5 + 4H_2O,$$

which takes place very slowly.

Procedure 45. — Heat the solution of the sulphides (P. 42), which should contain 10 ccm. HCl (1.20) in a total volume of 50 ccm., to

about 90°, and pass in H_2S gas for about 5 minutes, keeping the solution at about 90°. If no precipitate appears, add about 5 ccm water, and again saturate with H_2S at the same temperature as before. (Orange red precipitate, presence of ANTIMONY.) Filter while hot, add 5 ccm. water, heat the filtrate nearly to boiling, again saturate with H_2S to ensure complete precipitation of antimony, and filter if any precipitate forms. Wash the precipitates with hot water. (Precipitate, P. 46; filtrate, P. 47.)

Notes. — 1. By following carefully the directions given in P. 42 and this procedure, a good separation of antimony and tin may be obtained; when only 1 mgm. of antimony is present it is precipitated as Sb_2S_3, while even 500 mgm. of (stannic) tin give no precipitate. If, however, the HCl solution be too concentrated, a small quantity of antimony will escape detection; hence the precaution of adding a little water to the solution and repeating the treatment with H_2S. If the HCl solution be too dilute, or if it be not kept hot, some SnS_2 may precipitate when a large amount of tin is present. When mixed with a little Sb_2S_3 a brown precipitate results.

2. If mercury or copper be present in the substance and ammonium polysulphide has been used, HgS or CuS may be precipitated at this point as a gray or black precipitate.

Procedure 46. — Dissolve the H_2S precipitate (P. 45) in a little strong HCl in a small casserole and evaporate the solution to about 1 ccm. Introduce beneath the solution a piece of platinum foil and place upon it a piece of pure tin. After several minutes wash carefully with water and cover the platinum foil with (alkaline) NaOCl solution. (Black deposit on the platinum undissolved by NaOCl, presence of ANTIMONY.) (Precipitate and solution, reject.)

Notes. — 1. Mercury and copper, if present, will also be precipitated in the metallic condition upon the platinum, but the antimony may be easily distinguished from them by its black color. Tin is used rather than zinc in precipitating the antimony, since zinc would also precipitate tin from the solution.

2. The treatment with NaOCl serves to prove that the black precipitate does not consist of arsenic or tellurium; for these elements are readily dissolved by it, while antimony is not. Since, however, several milligrams of arsenic must be present before the treatment with tin would give a deposit on the platinum, an arsenic deposit will probably never be obtained in an actual analysis.

Procedure 47. — Cool the filtrate from the H_2S precipitate (P. 45), dilute with 20 ccm. water, and pass in H_2S for 10 minutes. (Yellow precipitate, presence of TIN.) If there is a precipitate, evaporate the mixture without filtering to 5–10 ccm., add about 1 gram of granulated zinc, and allow the action to continue for several minutes, but not until all the zinc is dissolved. (Gray, spongy precipitate, presence of TIN.) Decant the solution into a test tube, allow any particles suspended in it to settle out, decant again, and unite the two residues. Heat the residues with 2–5 ccm. HCl (1.20) until everything (except any particles of carbon) is dissolved. Dilute the solution with one-half its volume of water, and pour it at once through a small filter into 5 ccm. $HgCl_2$ solution. (White precipitate, presence of TIN.)

Notes. — 1. The solution is precipitated with H_2S in the cold, because a small quantity of SnS_2 would not separate from a hot solution unless the acid were more diluted. The addition of much water is avoided, since it has to be evaporated off in the confirmatory test.

2. In the confirmatory test the precipitate of SnS_2 is not filtered off, but is dissolved by concentrating the acid by evaporation, since it clogs the filter and tends to pass through it. The zinc must not be allowed to dissolve entirely, since the tin might then also dissolve. Care must also be taken not to lose it in the process of decantation or by failing to dissolve it completely. Finally, since $SnCl_2$ oxidizes rapidly in the air, the solution in HCl must be immediately added to the $HgCl_2$ solution. If these precautions are observed, the presence of half a milligram of tin in the HCl solution of the sulphides (P. 4) may be detected after some practice. The confirmatory test is, however, less delicate than the precipitation by H_2S, but it is more characteristic, since $SbCl_3$, even if present, does not reduce $HgCl_2$.

Test Analyses

Numerous analyses were made to test the efficiency of the process above described. Nearly all of those which were made after the procedure assumed final form are reproduced in the tables below. In these tables the numbers in each vertical column show the weights in milligrams of the various elements which the solution submitted to analysis contained. The results of the tests for each element are shown by the letters following these numbers. That the result was satisfactory is indicated by the letter S; that is, when the element was present, that the test for it, however small, was unmistakable, and therefore conclu-

sive; and when the element was absent, that a good blank test was obtained. When the test was very small, especially in comparison to the quantity of the element present, though still unmistakable, this is sometimes indicated by the symbol S—. When in the presence of the element the test failed, or in its absence a result was obtained that might be thought to indicate its presence, the letter F is used. When the result was doubtful or inconclusive, owing to the appearance or small size of the precipitate, this is indicated by the letter D. When the test was not tried, if the element was present, a dash is used in place of a letter; or, if the element was not present, dots are inserted.

Silver Group

All these analyses (Nos. 1–9) were begun at P. 11 and carried through P. 15.

T. A. No.	1	2	3	4	5, 6	7	8	9
Pb	500 S	500	. .	. .	. .	. .	. .	. .
Ag	0 S	1 S	500 S	500 S	0 S	1 F	1 S—	2 S
Hg	0 S	1 S	0 S	1 S	500 S	500 S	500 S	500 S

Copper Group

The following analyses (Nos. 10–20) were begun at P. 21 and were carried through P. 23–30, P. 22 being omitted. In addition, tin was tested for by P. 25, 41, 42, 45, and 47.

T. A. No.	10	11	12	13	14	15
Hg	500 S	500 S	500 S	500 S	1 S—	0 S
Sn (ous)	0 S	2 F	4 S	2 S—, F[1]	2 S—, F[1]	0 S
Pb	0 S	1 S—	1 F	2 S	1 S	0 S
Bi	0 S	1 S	1 S	0 S	500 S	500 S
Cu	0 S	1 S	1 S	0 S	1 S	0 S
Cd	0 S	1 S	1 S	0 D[2]	1 S	0 S

T. A. No.	16	17	18	19	20
Hg	0 S	1 S	0 S	1 S	2 S
Sn (ous)	0 S	2 S	0 S	2 S	0 S
Pb	0 S	1 S	0 S	1 F	1 S
Bi	0 S	1 S	0 S	1 S	1 S
Cu	500 S	500 S	0 S	1 S	1 S
Cd	0 D[2]	1 S	500 S	500 S	500 S

The following analyses (Nos. 21–28) were begun at P. 21, the H_2S precipitate was digested once with 10 ccm. ammonium polysulphide (P. 22), and the residue analyzed by P. 23–30.

T. A. No.	21	22	23	24	25	26	27	28
Hg (ic)	2 S	1 D	. .	. .	. .	. .	. .	. .
Cu	. .	. .	2 S—[3]	5 S	3 S	2 S	2 S[3]	3 S
Bi	. .	. .	. .	. .	. .	500 S	. .	. .
Sn (ous)	. .	. .	300 S	300	300	. .	50 S	. .
Sb (ous)	300 S	300 S	. .	. .	. .	. .	. .	200 S

The following analyses (Nos. 29–30) were made in the same way, except that 25 ccm. ammonium monosulphide were used.

T. A. No.	29	30
Hg (ic)	1 S	1 S
Cu	1 S[5]	1 F
Sb (ic)	300 —	. .
As	. .	250 —
Sn (ic)	. .	250 —

Tin Group

In the following analyses (Nos. 31–56) the substances were dissolved directly in ammonium polysulphide and the solution treated by P. 41–47.

T. A. No.	31	32, 33	34, 35, 36	37, 38	39, 40	41, 42, 43	44, 45	46	47
As	0 S	2 S	1 S	500 S	. .	. .	. .	. .	. .
Sb	500 S	500 S	500 S	0 S	0 S	1 S	500 S	500 S	500 S
Sn	. .	. .	. .	0 S	500 S	500 S	0 S	1 S—[6]	1 S

T. A. No.	48	49	50	51	52	53, 54	55	56
As	0 S	1 S	. .	2 S	1 S	500 S	500 S	500 S
Sb	0 S	1 S	1 S	2 S	200 S	1 S	1 S	0 S
Sn	500 S	500 S	1 S	2 S	500 S	1 S	1 S—, F[1]	1 S

In the following experiments (Nos. 57–90), in which a large quantity of an element of the copper group was present with the tin group, the analysis was begun at P. 21, the H_2S precipitate was treated once with 10 ccm. ammonium polysulphide, and the solution analyzed by P. 41–47. The copper-group residue was not treated by P. 23–25 to recover tin.

T. A. No.	57	58	59	60	61	62
Bi	500 —	500 —	500 —	500 —	500 —	500 —
As	0 S[7]	1 F	2 S	1 S	. .	. .
Sb (ous)	0 S	1 S	2 S	0 S	. .	. .
Sn (ous)	0 S	1 F	2 S	0 S	2 S	1 S[8]

T. A. No.	63	64	65	66	67	68
Hg	500	500 —	500 —	500 —	500 —	500 —
As	0 S[7]	1 S	2 S	0 —	. .	. .
Sb (ous)	0 S	1 S	2 S	0 S	. .	. .
Sn (ic)	0 S	1 F	2 F	5 F	5 F	10 S[9]

T. A. No.	69	70	71	72	73	74	75
Cu	500 —	500 —	500 —	500 —	500 —	500 —	500 —
As	0 S [7]	1 S	2 S	0 S	. .	. .	. .
Sb (ous)	0 S	1 S	2 S	0 S	. .	. .	. .
Sn (ous)	0 S	1 F	2 F	2 F	4 S—, F [1]	5 S [9]	3 S—, F [1] (stannic)

T. A. No.	76	77	78	79, 80	81	82	83	84
Cd . . .	500 —	500 —	500 —	500 —	500 —	500 —	500 —	500 —
As . . .	0 S	2 S	1 S	1 S	0 S	. .	. .	
Sb (ous)	0 S	2 S	1 S	1 S	0 S	. .	. .	
Sn (ous)	0 S	2 F	0 S	2 F	10 F	10 S—, F [1]	15 S [8]	15 S—, F [1]
Sn (ic) .	0 S	. .	. .	. .	. .	. .	. .	. .

T. A. No.	85	86	87, 88	89	90
Cd	500 —	500 —	500 —	500 —	500 —
As	. .	. .	. .	. .	. .
Sb (ous)	. .	. .	. .	. .	. .
Sn (ous)	20 S [9]	25 S—, F [1]	25 S	. .	. .
Sn (ic)	. .	. .	. .	3 F	5 S [9]

The following analyses (Nos. 91–97) were made by Mr. A. L. Smith in the same way as the preceding ones, except that 25 ccm. ammonium monosulphide, instead of 10 ccm. polysulphide, were used in digesting the H_2S precipitate.

A. T. No.	91	92	93	94	95	96	97
Hg (ic)	. .	. .	. .	. .	. .	. .	500 —
Bi	500 —	500 —	. .	. .	500 —	. .	. .
Cd	. .	. .	. .	500 —	. .	250 —	. .
Cu	. .	. .	500 —	. .	. .	250 —	. .
As (ic)	. .	. .	. .	. .	. .	. .	1 S
Sb (ic)	2 S	4 S	2 S	2 S	1 S	1 S	1 S
Sn (ic)	5 F[12]	10 F[12]	5 S	5 S	5 F[12]	5 F[12]	5 F[12 13]

In the following analyses (Nos. 98–100), also made by Mr. A. L. Smith, the solution in ammonium monosulphide and the residue were treated separately in order to detect tin. It was not detected in any case in the analysis of the solution. The results shown in the table were obtained in the analysis of the residue.

T. A. No.	98	99	100
Hg (ic)	250 —	250 —	. .
Bi	250 —	250 —	. .
Cd	. .	. .	250 —
Cu	. .	. .	250 —
Sn (ic)	2 F	5 S	3 S —, F[1]

Mixtures Containing the Rarer Elements

The following analyses were made, starting at P. 41, with an ammonium polysulphide solution, and following P. 42, 43, and *P. 43*a*–43*c*.

T. A. No.	101	102	103	104	105
As	. .	. .	300 S	200 S	200 S
Sb	. .	. .	200 —	. .	. .
Sn	. .	. .	200 —	200 —	200 —
Se	0 S	1 S	1 S	1 S	0.5 S
Te	0 S	1 S	1 —	2 S	1 S
Mo	100 S	50 S	1 S	0 S	0.5 S

The following analyses were begun at P. 21, the H_2S precipitate was extracted with ammonium polysulphide (P. 22), the solution was analyzed by P. 41–43 and *P. 43*a*–43*c*, and the residue treated by P. 23, 24, and *P. 24*a*.

T. A. No.	106	107	108
Cu	300 —	200 —	100 —
Hg	0 S	0 S	0 S
Pt	5 S^{11}	3 S^{10}	2 S^{10}
Au	5 S^{10}	3 S^{10}	1 S^{11}
Te	. .	. .	10 S

The following analyses (Nos. 109–111) were made by Mr. A. L. Smith, beginning with P. 21 and following through the whole process as described in P. 21–47. Ammonium monosulphide was used in separating the copper and tin groups.

T. A. No.	109	110	111	112[18]	113
Hg (ic)	1 D[14]	1 —	1 F[14]	. .	2 D[14]
Pb	1 F	1 S	1 S—	. .	1 S
Bi	0 S	1 S[19]	1 S[19]	. .	1 S
Cd	1 D	1	1 F[16]	1 S	2 S
Cu	1 S	1 S	1 S	. .	1 S
As (ic)	1 F	1 S	1 S	. .	1 S
Sb (ic)	0 S	1 S	1 S—	1 S	1 S
Sn (ic)	2 S	1 S—, F[1]	1 S—, F[1]	. .	2 S
Ir	1 S[15]	1 S[20]	1 S .	. .	1 S[15]
Au	1 S[15]	1 S[20]	1 S[15]	. .	1 S[15]
Se	1 F	1 F[21]	1 S—	1 S	2 F[21]
Te	1 F	1 F	1 S—[17]	1 S	2 F[22]
Mo	1 D	1 D	1 S—[17]	1 S	2 S

[1] The confirmatory test with $HgCl_2$ failed, but a distinct precipitate of SnS_2 was obtained.

[2] A very small, dark precipitate was obtained.

[3] No blue color was produced with NH_4OH, but a slight pink precipitate with $K_4Fe(CN)_6$ was visible on the filter.

[4] A good blue color was obtained with NH_4OH, showing that a small quantity of copper is not dissolved out of a large copper-group precipitate by the polysulphide.

[5] No blue color could be seen, but a very distinct pink precipitate formed with $K_4Fe(CN)_6$.

[6] In this analysis the confirmatory tin test failed, but this was doubtless due to the fact that the SnS_2 precipitate was filtered off and dissolved in HCl, instead of evaporating the mixture as usual.

[7] The HCl precipitate from the polysulphide solution was very light-colored, or, if not, when it was extracted with NH_4OH the solution gave no precipitate with HCl; so the analysis was not carried further.

[8] A fair SnS_2 precipitate was produced, but owing to an accident the confirmatory test was not tried.

[9] The SnS_2 precipitate produced in P. 47 was estimated to contain only 1–3 mgm. Sn.

[10] In these analyses the moist H_2S precipitate was left on the filter for several hours before treating with ammonium polysulphide.

[11] Satisfactory tests were obtained for gold and for platinum both in the copper and tin groups; and the final precipitates were not far from equal in size.

[12] No precipitate of SnS_2 was produced in P. 47.

[13] The residue undissolved by ammonium sulphide was treated by P. 23, 24, 25, 41, and 42, and the HCl solution so obtained reduced directly with Zn, the residue dissolved, and $HgCl_2$ added; but no test for tin was obtained.

[14] A black precipitate was produced in the test with $SnCl_2$, probably due to the presence of gold. It was treated with hot HNO_3 (1.20), and it did not dissolve, showing it was not wholly mercury; the solution after evaporation with HCl was tested with $SnCl_2$, but only an inconclusive turbidity was obtained.

[15] Tests for these elements were obtained in the analyses of both the copper and tin groups.

[16] All or nearly all the cadmium failed to be precipitated by H_2S from the 100 ccm. of solution containing 4 ccm. HCl (1.12), even though the gas was passed in for 10 minutes; for it was recovered from the filtrate by adding 50 ccm. more water and passing in H_2S for 10 minutes, and then confirmed by P. 23, 27, and 30.

[17] Nearly all the tellurium and molybdenum failed to be precipitated by H_2S; for they were recovered from the filtrate by adding NH_4OH and NH_4SH and acidifying, and were detected by treating the precipitate by P. 43, *43*a*, *43*c*, *43*d*, and *43*e*.

[18] In T. A. No. 112 the last part of P. 43 and *P. 43*b* were omitted.

[19] No distinct turbidity was visible, but upon filtering and treating with sodium stannite the filter was much darkened.

[20] Tests for these elements were obtained only in the analysis of the tin group.

[21] A red precipitate separated in the lead test upon evaporating with H_2SO_4, which was probably selenium, and indicated that it had not been dissolved out by $(NH_4)_2S$.

[22] In testing for arsenic with $MgCl_2$ a flocculent precipitate accompanied the crystalline one of $MgNH_4AsO_4$, and on dissolving this in HCl and adding H_2S a black precipitate resulted. This was dissolved in HCl and $KClO_3$ and treated by *P. 24*d*: a black precipitate resulted, showing that tellurium was precipitated with the arsenic.

The test analyses of the silver group (Nos. 1–9) show that 1 mgm. of mercurous mercury is detected in the presence of 500 mgm. of either lead or silver; and that 1 mgm. of silver is detected without difficulty in the presence of 500 mgm. of lead, but that in the presence of 500 mgm. of mercury 1 mgm. of silver lies at about the limit of detectability.

The test analyses of the copper group (Nos. 10–20) show (at any rate when the ammonium sulphide treatment is omitted) that even 1 mgm. of mercury, bismuth, copper, or cadmium is detected in the presence of 500 mgm. of any other one of these elements; that with lead in presence of 500 mgm. of any one of these elements 1 mgm. is near the limit, probably owing to the difficulty of securing complete precipitation with H_2S; and that with stannous tin the limit of detectability is at 2 mgm. The blank tests were satisfactory in all cases, except that a very small, dark precipitate was sometimes obtained in the cadmium test with H_2S. Even when the H_2S precipitate was treated

with ammonium polysulphide (T. A. Nos. 21–28), which dissolves some copper and mercury, these elements were detected in all cases where 2 mgm. were present; and when monosulphide was used (as in T. A. Nos. 29–30) 1 mgm. of mercury was twice detected, while with copper it was found in one analysis and lost in the other.

The test analyses of the tin group in which the copper group was not present, which were begun with an ammonium polysulphide solution of the elements (Nos. 31–56), show that 1 mgm. of arsenic, antimony, or tin is invariably detected, even in the presence of 500 mgm. of any other one of these elements.

The test analyses in which the elements of the tin group were associated with 500 mgm. of an element of the copper group and in which the H_2S precipitate was treated with ammonium polysulphide (Nos. 57–90) show that 1 mgm. of arsenic or antimony is almost always detected; but that a much larger quantity of tin in some combinations is not detected, if only the ammonium sulphide solution is analyzed for it. Thus, while in the presence of bismuth 1 to 2 mgm. of stannous tin were found, yet in the presence of copper 4 to 5 mgm., and in that of cadmium 10–15 mgm. of it were lost; and 3 to 5 mgm. of stannic tin were lost in the presence of mercury or cadmium.

In the analyses in which ammonium monosulphide was used (Nos. 91–97), the detection of antimony in the higher state of oxidation and of arsenic is nearly as satisfactory, 1 or 2 mgm. having been always found; but a larger quantity of stannic tin remains with the copper group than when the polysulphide is used, 5 mgm. being retained even by bismuth.

These results clearly show the necessity of testing for tin in the analysis of the copper as well as of the tin group, and T. A. Nos. 98–100 show that it can be detected in the copper group analyses when 3 mgm. are present.

In the test analyses with mixtures containing the rarer elements (Nos. 101–113) 1 mgm. of platinum or gold was always detected; and the same was true of 1 mgm. of selenium, tellurium, and molybdenum in the analyses that started at the beginning of the tin group, but not in those where elements of the copper group were present and the analysis was begun with the H_2S precipitation.

Confirmatory Experiments and References

Analysis of the Silver Group

P. 11, N. 1: Solubility of $PbCl_2$ and TlCl in Water and in HCl. — See Noyes, *Z. phys. Chem.*, 9, 614, 623 (1892); Engel, *Ann. chim. phys.*, (6) 17, 359 (1889); Ditte, *Compt. rend.*, 92, 718 (1881).

P. 13, N. 1: Solubility of $PbSO_4$. — See C. E., P. 26, N. 1.

**P. 13a, N. 1: Test for Thallium with KI.* — To 50 mgm. Pb as $PbCl_2$, dissolved in 20 ccm. water, 5 ccm. H_2SO_4 (1.84) were added; the mixture was cooled and filtered, and to the filtrate a few drops KI solution were added: no precipitate appeared.—The experiment was repeated, except that 1 mgm. Tl as Tl_2SO_4 was also present: a pale yellow precipitate of TlI resulted.

To solutions containing 0.5 mgm. Tl as Tl_2SO_4 and 4 ccm. HCl (1.12) and 10 ccm. or 20 ccm. water, respectively, a few drops of a normal KI solution were added: a yellow precipitate separated in the first experiment, but only a faint yellow turbidity appeared in the second.

**P. 13a, N. 2: Oxidation of Thallous Salts.* — 100 mgm. Tl as Tl_2SO_4 were dissolved in 10 ccm. HNO_3 (1.42) and evaporated to about 2 ccm.; the solution was diluted to 20 ccm. and 1–2 ccm. HCl (1.12) added: a large light-yellow precipitate separated, thus showing that some, but not much, of the thallium had been oxidized.

100 mgm. Tl as Tl_2SO_4 were dissolved in 2 ccm. HNO_3 (1.42) and about 5 ccm. HCl (1.20) were added: a white precipitate separated at first, but dissolved on warming. The mixture was evaporated to about 2 ccm., cooled, and diluted to 20 ccm.: no precipitate separated, even when a little HCl was added, thus showing that the thallium was in the thallic state. — The experiment was repeated, except that the *aqua regia* solution was evaporated to dryness and the residue dried by heating slightly; to it 4 ccm. HCl (1.12) and 20 ccm. water were added: a large light-yellow precipitate separated, showing that the thallic salt had been largely but not completely reduced.

P. 14, N. 1: Explanation of the Solubility of $PbSO_4$ in Ammonium Acetate Solution. — See Noyes and Whitcomb, *J. Am. Chem. Soc.*, 27, 747 (1905).

P. 14, N. 2: Behavior of Bismuth Compounds towards Ammonium Acetate and K_2CrO_4. — 5 mgm. Bi as solid bismuth oxysulphate (see P. 26, N. 5) were treated by P. 14, 20 ccm. normal ammonium acetate and 5 ccm. 5-normal acetic acid being used: a yellow precipitate very similar in appearance to $PbCrO_4$ was formed on the addition of K_2CrO_4, but this dissolved quickly in the acetic acid. — The experiment was repeated with 1 mgm. Bi as nitrate: the result was the same.

P. 15, N. 1: Molecular Formula of Gaseous Mercurous Chloride. —

Baker (*J. Chem. Soc. Trans.*, 77, 646. 1900) has shown that absolutely dry mercurous chloride vapor has a density corresponding to the formula Hg_2Cl_2.

Condition of Mercurous Salts in Solution. — See Ogg, *Z. phys. Chem.*, 27, 290–299 (1898); Abel, *Z. anorg. Chem.*, 26, 377 (1901).

Action of NH_4OH on Hg_2Cl_2. — For the evidence that the black residue is a mixture of Hg and $HgClNH_2$, see Barfoed, *J. prakt. Chem.*, 39, 201 (1889); Pesci, *Gazz. chim. ital.*, 21, 569 (1891); and Sen, *Z. anorg. Chem.*, 33, 197 (1903).

P. 15, N. 3: Complex Silver-Ammonia Anions. — See Bodländer and Fittig, *Z. phys. Chem.*, 39, 597 (1902); Whitney and Melcher, *J. Am. Chem. Soc.*, 25, 69 (1903); Bodländer and Eberlein, *Z. anorg. Chem.*, 39, 197 (1904); Lucas, *Z. anorg. Chem.*, 41, 193 (1904).

P. 15, N. 5: Solubility of AgCl in Chloride Solutions. — See Comey, *Dictionary of Solubilities*, p. 373.

1 mgm. Ag as AgCl was dissolved in 5 ccm. NH_4OH (0.96), the solution obtained was made acid with HCl: no precipitate separated. — The experiment was repeated, using HNO_3 instead of HCl: a precipitate formed. — 5 mgm. Ag as AgCl were dissolved in 15 ccm. NH_4OH (0.96), and the solution made acid with HCl: no precipitate separated. An equal volume of water was added: AgCl precipitated.

Precipitation and Separation of the Copper and Tin Groups

P. 21, N. 1: Order of Precipitation of the Sulphides of the Copper and Tin Groups from Cold HCl Solution. — 2 mgm. As as As_2O_3, 2 mgm. Hg. and 2 mgm. Cu, each as chloride, were in separate experiments dissolved in 2 ccm. HCl (1.20), and 2 mgm. of each of the elements of the copper and tin groups were in separate experiments dissolved in 4 ccm. HCl (1.12); each solution was put into a small bottle, saturated completely with H_2S at room temperature, the bottle corked, and allowed to stand 15 minutes. In cases where no precipitate formed the solution was successively diluted with measured quantities of water, being again saturated with H_2S and allowed to stand after each addition: the most strongly acid solution from which each element separated is shown by the following table:

Ccm. HCl (1.20)	2	. .	. .	. .	. .	. .
Ccm. HCl (1.12)	. .	4	4	4	4	4
Ccm. water	0	0	4	12	44	96
Elements precipitated	As	Hg, Cu	Sb	Bi, Sn (ic)	Cd	Pb, Sn (ous)

The cadmium, lead, and stannous sulphides precipitated slightly and only after several minutes; the others almost at once.

Order of Precipitation of the Sulphides of the Iron Group from Weak Acid Solutions. — 50 mgm. Zn and 500 mgm. Zn as nitrate, 500 mgm. Fe (ous), 500 mgm. Ni, 500 mgm. Co, and 500 mgm. Mn as sulphate were in separate experiments dissolved in 1 ccm. HCl (1.12) and 100 ccm. water, saturated with H_2S at room temperature, and allowed to stand 10 minutes: zinc was precipitated from both its solutions, but none of the other elements. — The experiments with 50 mgm. Zn and 500 mgm. Zn were repeated, except that 2 ccm. HCl (1.12) was used: ZnS precipitated after several minutes in the 500 mgm. portion, but not in the 50 mgm. one.

500 mgm. each of ferrous Fe, Co, Ni, and Mn as sulphate were dissolved in 100 ccm. water and saturated at room temperature with H_2S for 10 minutes: FeS slowly precipitated in considerable quantity, but none of the other sulphides. — The experiment was repeated, except that the substances were dissolved in 10 ccm. 10% acetic acid solution, 1 ccm. 10% $NaC_2H_3O_2$ solution, and 90 ccm. water: the result was the same. The last experiment was repeated, except that 10 ccm. instead of 1 ccm. $NaC_2H_3O_2$ solution were used: large quantities of NiS and CoS as well as of FeS precipitated, but no MnS. — In another experiment 500 mgm. Mn as $MnSO_4$ were dissolved in 1 ccm. 10% $HC_2H_3O_2$ solution, 10 ccm. 10% $NaC_2H_3O_2$ solution, and 90 ccm. water, and saturated with H_2S: no MnS precipitated.

P. 21, N. 3: Precipitation of Arsenic, Platinum, and Molybdenum by H_2S. — 100 mgm. As as H_3AsO_4, 100 mgm. Mo as H_2MoO_4, and 25 mgm. Pt as H_2PtCl_6 were dissolved in separate 100 ccm. portions of dilute HCl (one volume HCl (1.12) to twenty-five volumes water) and were saturated with H_2S in the cold: less than 1 mgm. of As and of Pt, but considerable Mo, precipitated as sulphides in 10 minutes. The three solutions were then filtered, heated to boiling, and saturated with H_2S at that temperature for about 15 minutes: a large precipitate resulted in each case. The solutions were filtered, saturated in the cold with H_2S, and heated in pressure bottles in the steam bath for 1 hour: a considerable precipitate separated from each solution, estimated to contain about 5 mgm. As in the arsenic solution and 10 mgm. Mo in the molybdenum solution.

100 mgm. As as H_3AsO_4 were added to 100 ccm. HCl (1.20) and saturated in the cold with H_2S: a large yellow precipitate separated. After 5 minutes the mixture was diluted with half its volume of water and filtered; the filtrate was heated to 100° and H_2S passed in for 10 minutes: a small precipitate estimated to contain only 3–5 mgm. As resulted. These two experiments with arsenic acid show that the precipitation takes place much more rapidly in the presence of concentrated HCl.

Precipitation of Cadmium and Lead by H_2S. — Separate solutions contain-

ing 5 mgm. Cd, 5 mgm. Pb, 10 mgm. Cd, and 10 mgm. Pb, respectively, in 100 ccm. of a mixture of one volume HCl (1.12) and fifteen volumes water were saturated in the cold with H_2S for 15 minutes: precipitates began to form only after 10 or 15 minutes in each of the solutions.

Separate solutions containing 1 mgm. Cd and 1 mgm. Pb in 100 ccm. of a mixture of one volume HCl (1.12) and twenty-five volumes water were saturated in the cold with H_2S: both solutions showed precipitates, but that in the case of lead was scarcely visible until it was collected on a filter. The PbS was filtered out and NH_4OH and $(NH_4)_2S$ added to the filtrate: a brown color corresponding to 0.1–0.2 mgm. Pb resulted, showing that substantially all the lead was precipitated.

Precipitation of Zinc by H_2S. — Solutions containing 500 mgm. Zn in three 100 ccm. portions of dilute HCl, containing one volume HCl (1.12) to twenty-five volumes water, to forty volumes water, and to fifty volumes water, respectively, were saturated in the cold with H_2S, then heated to boiling, and again saturated with H_2S: in the cold, H_2S failed to produce a precipitate in any of the solutions in 5 minutes; but on heating, a slight precipitate formed in the 1 : 40, and a heavy one in the 1 : 50, but none in the 1 : 25 mixture.

Precipitation of Titanium Hydroxide by Hydrolysis. — Separate 100 mgm. portions of Ti in 100 ccm. dilute HCl, containing one volume HCl (1.12) to twenty volumes water, to ten volumes water, and to eight volumes water, respectively, were saturated cold with H_2S and then heated in pressure bottles in a steam bath for 2 hours: in the 1 : 20 volume solution a very large white precipitate had formed in 30 minutes; the 1 : 10 solution remained clear for 45 minutes, and then showed only a turbidity: and the 1 : 8 solution remained unchanged during the 2 hours.

Precipitation of Bismuth and Antimony Oxychlorides by Water. — Separate solutions containing 500 mgm. Bi as nitrate, 400 mgm. Sb as $SbCl_3$, and 300 mgm. Sb as Sb_2O_5 (obtained by evaporating an $SbCl_5$ solution with *aqua regia*) were evaporated with HCl almost to dryness; 4 ccm. HCl (1.12) and 36 ccm. water were added, and the mixture was heated: from the bismuth solution no precipitate separated either in the cold or upon heating; in the antimonous solution a large white precipitate formed in the cold, but dissolved almost completely upon heating; and in the antimonic solution a large precipitate separated in the cold and did not appear to dissolve upon heating. To the bismuth solution 20 ccm. more water were added: a white precipitate then began to form.

P. 21, N. 3: Separation of the Copper and Tin Groups from the Iron Group by H_2S. — Mixtures of elements as shown below were dissolved in 4 ccm. HCl (1.12) and 36 ccm. water and treated exactly as described in P. 21, except that the solutions containing cadmium were diluted at once

to 100 ccm. and saturated at room temperature with H_2S; the solutions were filtered after 10–30 minutes, the filtrate boiled to expel H_2S, HNO_3 added, the mixture again boiled, NH_4OH added to detect iron, any precipitate filtered off, and H_2S was passed into the filtrate or $(NH_4)_2S$ was added to it to detect zinc, nickel, or cobalt: the results are recorded below as in the Test Analyses:

Cd	500 —	500 —	500 —	500 —	500 —
Zn	0 S	2 S	1 S[1]	. .	. .
Fe	0 S	. .	. .	2 S	1 S
Ni	0 S	. .	. .	. .	1 S
Cu	500 —	500 —	. .	. .	. .
Bi	. .	. .	200 —	200 —	. .
As (ous)	. .	. .	100 —	100 —	. .
Sb (ous)	. .	. .	100 —	100 —	. .
Sn (ic)	. .	. .	200 —	200 —	. .
Zn	. .	. .	1 S[1]	. .	. .
Fe	1 S	0 S	. .	. .	. .
Ni	1 S	. .	. .	1 S	. .
Co	. .	1 S[2]	. .	. .	. .

[1] A nearly white precipitate was obtained with $(NH_4)_2S$.

[2] The black $(NH_4)_2S$ precipitate was dissolved in *aqua regia* and the solution evaporated just to dryness: the residue had a slight pink color.

P. 21, N. 4: Composition of the H_2S Precipitates. — From solution of $HgCl_2$ in excess, see Rose, *Pogg. Ann.*, **13**, 64 (1828). From arsenic acid solutions, see C. E., P. 44, N. 1, 2, and 3. From antimonic solutions, see Klenker, *J. prakt. Chem.*, **59**, 150 (1899). From chloroplatinic acid, see Antony and Lucchesi, *Gazz. chim. ital.*, **26**, 211 (1896). From gold chloride, see Hoffmann and Krüss, *Ber. d. chem. Ges.*, **20**, 2369, 2704 (1887). From selenous acid, see Ditte, *Compt. rend.*, **73**, 625, 660 (1871); Divers and Shimidzu, *J. Chem. Soc.*, **47**, 441 (1885). From tellurous acid, see Becker, *Liebig's Ann. Chem.*, **180**, 260 (1875).

P. 21, N. 5: Action of HNO_3 on H_2S. — Separate 50 ccm. portions of mixtures of one volume of HNO_3 (1.20) in 2.5, 5, 10, and 20 volumes of solution were heated to boiling and saturated with H_2S at that temperature: in the first solution a precipitate of sulphur soon appeared, in the

second a slight precipitate formed after 10 minutes, and in the last two no precipitates formed in 20 minutes.

P. 22, N. 1: Solubility of SnS and Sb_2S_3 in Ammonium Monosulphide. — See C. E., P. 22, N. 4.

P. 22, N. 2: Hydrolysis of the Alkaline Sulphides and Composition of the Polysulphides. — It has been shown by C. F. Sammet (*Thesis, M. I. T.*, 1903) that a solution of the empirical composition $(NH_4)_2S$ containing 0.1 formula weight per liter is practically completely hydrolyzed into NH_4OH and NH_4SH, and that in the same solution the latter is only slightly (roughly, 0.3%) hydrolyzed into H_2S and a second equivalent of NH_4OH. But in a solution containing only half as much NH_4OH, *i. e.*, in a solution containing 0.1 formula weight NH_4SH per liter, the degree of hydrolysis increases to several per cent.

Küster and Heberlein (*Z. anorg. Chem.*, 43, 71. 1905) have found Na_2S in a solution containing 0.05 formula weights per liter to be 86% hydrolyzed into NaOH and NaSH, and NaSH in 0.01 normal solution to be only 0.15% hydrolyzed into NaOH and H_2S. For the degree of hydrolysis of NaSH, Walker (*Z. phys. Chem.*, 32, 137. 1900) found practically the same value by an independent method.

Küster and Heberlein also investigated the hydrolysis of the polysulphides of sodium, and showed that the degree of hydrolysis decreases with increasing sulphur-content; thus a solution of the composition Na_2S_2 was 65%, a solution of Na_2S_4, only 12% hydrolyzed. They found further that Na_2S solutions of the following concentrations when saturated with sulphur at 24° have the empirical composition Na_2S_x where x has the following values:

Formula weights Na_2S per liter	2.0	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{32}$
Value of x	4.48	4.84	5.12	5.24

It was found that x varied only slightly with the temperature. According to these authors, Na_2S_4, and less readily Na_2S_5, have been obtained in the solid form by evaporating aqueous solutions; but Na_2S_2 and Na_2S_3 have not been so obtained. All of these have, however, been crystallized from alcoholic solutions (H. Boettger, *Liebig's Ann. Chem.*, 223, 335. 1884; H. Rebs, *Liebig's Ann. Chem.*, 246, 358. 1888).

Bloxam (*J. Chem. Soc.*, 67, 300. 1894; 77, 753. 1900) found that a very concentrated ammonium sulphide solution prepared from NH_4OH (0.88) so as to have exactly the composition $(NH_4)_2S$ dissolved sulphur until the composition became approximately $(NH_4)_2S_{1.5}$. He has obtained under various special conditions the following solid salts: $(NH_4)_2S_4$, $(NH_4)_2S_5$, $(NH_4)_2S_7$, $(NH_4)_2S_9$, $(NH_4)_4S_7$, and $(NH_4)_4S_9$; Na_2S, NaSH, Na_2S_5, and Na_4S_9; K_2S, KSH, K_2S_3, K_2S_4, K_2S_5, K_4S_5, and K_4S_9.

P. 22, N. 2: Ammonium Salts of the Sulphoacids. — The following ammonium sulphosalts have all been prepared in the crystalline form by adding alcohol to concentrated solutions of the sulphides in ammonium sulphide: $(NH_4)_3AsS_3$ and $(NH_4)_3AsS_4$ (Berzelius. *Pogg. Ann.*, 7, 141 and 18. 1826); $(NH_4)_3SbS_3$ (Pouget, *Ann. chim. phys.* (7), 18, 532. 1899): $(NH_4)_3SbS_4$, $(NH_4)_3SbS_4.4H_2O$ (Stanek, *Z. anorg. Chem.*, 17, 121. 1898): $(NH_4)_3SnS_3.3H_2O$ and $(NH_4)_3SnS_3.7H_2O$ (Stanek, *loc. cit.*, p. 213). Certain other arsenous salts, including NH_4AsS_2, have also been prepared in the solid state. On evaporating a solution of Sb_2S_3 in $(NH_4)_2S$ in a vacuum at a low temperature, the meta salt NH_4SbS_2 is usually obtained; on evaporating at a high temperature, or on treating NH_4SbS_2 with water, solid $(NH_4)_2Sb_4S_7$ is formed. Berzelius states that a solution of the empirical composition $(NH_4)_2S$ saturated with As_2S_3 or As_2S_5 contains these substances in the proportion As_2S_3 : $2(NH_4)_2S$ or As_2S_5 : $2(NH_4)_2S$. Pouget finds that a solution of $(NH_4)_2S$ saturated with Sb_2S_3 contains less antimony than corresponds to the ratio Sb_2S_3 : $3(NH_4)_2S$. A K_2S or Na_2S solution dissolves sufficient Sb_2S_3 to give a solution of the composition Sb_2S_3 : $2K_2S$ or Sb_2S_3 : $2Na_2S$. There does not appear to be any direct evidence as to the nature of these salts in solution.

*Solid sulphosalts of the rare elements have been obtained from alkaline sulphide solutions as follows: K_3AuS_3 (Antony and Lucchesi, *Gazz. chim. ital.*, 26, 359. 1896); $3K_2S.TeS_2$, $3Na_2S.TeS_2$, and $3(NH_4)_2S.TeS_2$ (Berzelius); K_2MoS_4, $(NH_4)_2MoS_4$ (Berzelius, *Pogg. Ann.*, 7, 429. 1826; Krüss, *Liebig's Ann. Chem.*, 225, 29. 1884).

P. 22, N. 4: Solubility of the Sulphides of the Tin and Copper Groups in Ammonium Hydroxide, Monosulphide, and Polysulphide. — 500 mgm. As as As_2S_3, Sb as Sb_2S_3, Sn as SnS, Cu as CuS, Hg as HgS, Cd as CdS, Bi as Bi_2S_3, all freshly precipitated by H_2S, and 500 mgm. As as As_2S_5, 100 or 500 mgm. Sb as Sb_2S_5, and 100 or 500 mgm. Sn as SnS_2 all precipitated from ammonium polysulphide, were warmed (but not enough to cause boiling through escape of gas) in a covered casserole for about 5 minutes with (*a*) 15–20 ccm. NH_4OH (0.96); (*b*) 10 ccm. of the ammonium monosulphide reagent; and (*c*) 10 ccm. of the ammonium polysulphide reagent. The solutions were then filtered and the filtrates acidified with HCl. The amount dissolved was estimated from the size and color of the precipitate or from the amount of the undissolved residue. The results are given below: the numbers represent roughly the number of milligrams of the element dissolved, a + sign indicating that this amount dissolved readily and that probably much more would have dissolved.

	(*a*) NH_4OH (0.96).	(*b*) Monosulphide.	(*c*) Polysulphide.
As_2S_3	500 +	500 +	500 +
As_2S_5	500 +	500 +	500 +
Sb_2S_3	0.5–1	50–100	500
Sb_2S_5	100[1]	300	500 +
SnS	0[2]	0–3[2]	500
SnS_2	100[1]	300	500 +
CuS	0–0.3	0	5–10
HgS	3–10	0	1
CdS	0	0	0
Bi_2S_3	0	0	0

[1] Only about 100 mgm. of the element as sulphide was taken in these experiments.

[2] A few milligrams (5–15) of a yellow precipitate (SnS_2), containing little or no SnS were precipitated on acidifying the filtrate.

The orange Sb_2S_3 was found to be changed into the black variety, stibnite, by continued treatment with ammonium monosulphide, and black HgS was changed into the red modification by continued treatment with the polysulphide. It was also noted that the HgS which dissolves in NH_4OH may be precipitated by adding a few drops of monosulphide.

500 mgm. Cu and 500 mgm. Hg as freshly precipitated sulphides were in separate experiments warmed to 50° or 60° in covered casseroles with 25 ccm. ammonium monosulphide for 15 minutes; the residues were filtered off, and the filtrates made acid with HCl: a slight precipitate of sulphur separated, which was only very slightly darkened, thus showing that only an insignificant quantity of CuS or HgS had dissolved.

An ammonium monosulphide solution was prepared from NH_4OH (0.90) as described in N. 2, except that the solution was not diluted with the equal volume of water. From this solution several different ammonium polysulphide solutions were prepared, containing, respectively, 20, 10, 5, 3, and 1 grams dissolved sulphur in 200 ccm., and their solvent power for SnS and CuS tested as follows:

500 mgm. Sn as freshly precipitated SnS were warmed gently in a covered casserole with (*a*) 10 ccm. of these undiluted solutions; (*b*) 5 ccm. of them + 5 ccm. water; and (*c*) 5 ccm. of them + 10 ccm. water. The mixture was stirred frequently with a glass rod. The amount of tin in milligrams dissolved in a solution containing x grams dissolved sulphur in 200 ccm. and the time required to dissolve it are given below.

	$x = 10$ g.	$x = 5$ g.	$x = 3$ g.	$x = 1$ g.
(*a*) 10 ccm. undiluted	500 4 minutes	500 5 minutes	500 15 minutes	100 5 minutes
(*b*) 5 ccm. + 5 ccm. H_2O . . .	500[1] 5 minutes	500 10 minutes	. .	100 10 minutes
(*c*) 5 ccm. + 10 ccm. H_2O . .	500 8–10 minutes	. .	. .	. .

500 mgm. Cu as CuS were similarly treated for 5 minutes: the following table shows roughly the number of milligrams Cu as CuS that dissolved in a solution containing x grams dissolved sulphur in 200 ccm. where x has the stated values.

	$x = 20$ g.	$x = 10$ g.	$x = 5$ g.	$x = 3$ g.	$x = 1$ g.	$x = 0$ g.
(*a*) 10 ccm. of solution	25 +	. .	12	6	0.5	. .
(*b*) 5 ccm. + 5 ccm. H_2O . . .	. .	8[1]	4	3	0.2	0
(*c*) 5 ccm. + 15 ccm. H_2O . . .	. .	6–8	. .	. .	. .	. .

[1] The regular reagent described in N. 2 has this composition.

P. 22, N. 5: Solubility of the Sulphides of the Rarer Elements in Ammonium Sulphide. — Ribau (*Bull. soc. chim.*, 28, 241. 1877) has shown that pure, freshly precipitated PtS_2 is nearly insoluble in ammonium sulphide, but dissolves in large quantity when mixed with sulphides of either the tin or copper groups. — Under "Test Analyses of the Tin Group" it is shown that small quantities of platinum and gold divide almost equally between the copper and tin groups when copper is also present.

50 mgm. Mo as freshly precipitated sulphide were digested in a covered casseroie at 40–60° with 25 ccm. ammonium monosulphide for 15 minutes; the deep red solution was filtered and acidified with HCl: a precipitate estimated to contain about 35 mgm. Mo separated. The residue was digested a second time with 25 ccm. ammonium monosulphide: only about half the residue dissolved. — The experiment was repeated, using 10 ccm. portions of ammonium polysulphide: the result was the same, about two-thirds dissolving in the first treatment and about half the residue in the second.

200 mgm. Te were freshly precipitated with H_2S from a hot HCl solution containing 4 ccm. HCl (1.12) and 36 ccm. water; the black precipitate was digested with 25 ccm. ammonium monosulphide: the precipitate dissolved

completely in 3 or 4 minutes. The solution was acidified with HCl: a black precipitate separated. This was digested with 10 ccm. ammonium polysulphide; it dissolved immediately. To the solution HCl was added: a black precipitate separated.

200 mgm. Se as H_2SeO_3 were precipitated by Na_2SO_3 in an HCl (1.12) solution, as in *P. 43*c*. The red precipitate was filtered off and washed with HCl (1.12). It was then dissolved in hot HNO_3 (1.20); the solution was evaporated just to dryness and the residue dissolved in 4 ccm. of HCl (1.12) and 36 ccm. of water. The solution was heated to boiling and saturated with H_2S. A yellow precipitate which partly changed to red during the precipitation was produced. The solution was diluted to 100 ccm. and again saturated with H_2S in the cold; the precipitate was filtered off and digested with 25 ccm. ammonium monosulphide: the finely divided portion of the precipitate dissolved in a few minutes, forming a deep red solution, but the larger particles turned black on the surface and dissolved very slowly. After a few minutes the solution was filtered and the black residue digested successively three times with a fresh 25 ccm. portion of ammonium monosulphide: finally it all dissolved. The successive sulphide solutions were acidified with HCl (1.12): a bright yellow precipitate formed at first in every case, but that in the first solution gradually became orange within a few hours.

P. 22, N. 6: Extraction by Ammonium Monosulphide and Polysulphide of Arsenic, Antimony, and Tin Sulphides from those of the Copper Group. — See "Test Analyses of Tin Group."

Mixtures of 5, 10, 15, and 20 mgm. Sn as SnS with 500 mgm. Cd as CdS were digested at 80–90° with the ammonium polysulphide reagent in a pressure bottle for half an hour, and the solutions were analyzed by P. 41–47: the results recorded as in the Test Analyses were as follows:

Cd	500	500	500	500
Sn	5 F	10 F	15 D	20 S

The confirmatory test for tin (P. 47) failed in the experiment with 15 mgm. Sn. — The experiment was repeated with a mixture of 5 mgm. Sn as SnS_2 and 500 mgm. Cd as CdS: a small but satisfactory test for tin was obtained.

P. 22, N. 8: Coagulation of Colloidal Sulphides by NH_4NO_3. — In washing the various sulphides of the copper groups after the $(NH_4)_2S$ treatment, CuS, and especially CdS, sometimes passed through the filter in colloidal condition. To these colloidal mixtures was added enough solid NH_4NO_3 to make a 5% solution, and the mixtures were shaken and filtered: the filtrates were clear.

Analysis of the Copper Group

P. 23, N. 1: Solubility of the Copper Group Sulphides in HNO_3. — 500 mgm. of Pb, Bi, Cu, and Cd as sulphides were treated in separate experiments according to P. 23: the sulphides dissolved almost completely when the solution began to boil, but the sulphur residue remained dark-colored (except in the case of cadmium) even after several minutes' boiling.

500 mgm. Pb, Bi, Cu, and Cd as sulphides were in separate experiments boiled in an open casserole with about 30 ccm. of a mixture of one volume HNO_3 (1.20) and three volumes of water: Bi_2S_3 and CuS dissolved in 5 minutes or less, PbS dissolved less readily, and CdS only after 10–15 minutes. — The experiment was repeated, except that 50 ccm. of a still more dilute acid was used: the result was the same, except that solution took place somewhat less rapidly.

500 mgm. Hg as HgS were treated according to P. 23; and the filtrate was evaporated with excess of HCl to a small volume, diluted, and saturated with H_2S: a precipitate of HgS estimated to contain less than 1 mgm. Hg resulted. — The experiment was repeated, except that 30 ccm. HNO_3 (1.20) were used and the boiling continued for 10 minutes: a precipitate of HgS estimated to contain 2 mgm. Hg resulted. — The experiment was repeated, except that 30 ccm. of a mixture of one volume of HNO_3 (1.20) and three volumes of water were used and the boiling continued for 10 minutes: a precipitate of HgS containing about 0.5 mgm. Hg was formed. — 1 mgm. Hg as HgS was boiled with HNO_3 (1.20) for 10 minutes: no change in the amount of the sulphide was apparent.

P. 23, N. 4: Action of Strong HNO_3 on HgS. — 500 mgm. Hg as HgS were boiled for 10 minutes with 30 ccm. HNO_3 (1.42): the black precipitate had then become pure white. The filtrate was freed from HNO_3 and saturated with H_2S: a precipitate containing several milligrams Hg was formed. — The experiment was repeated, replacing the HNO_3 (1.42) by the strength used in P. 23: no change in the appearance of the precipitate took place.

P. *23, N. 5: Action of Dilute HNO_3 on Au and PtS_2.* — That small quantities of gold and platinum are not dissolved in P. 23 is shown by the results of Test Analyses, Nos. 106–113.

P. *23, N. 6: Oxidation of PbS to $PbSO_4$.* — 500 mgm. Pb as freshly precipitated PbS were treated according to P. 23, and to the filtrate $BaCl_2$ was added in large quantity: a precipitate of $BaSO_4$ estimated to correspond to 20–30 mgm. Pb was formed. — The experiment was repeated, except that the sulphide was boiled for 10 minutes with a more dilute acid, containing one volume HNO_3 (1.20) and three volumes water: the result was the same. — The experiment was repeated, except that HNO_3 (1.20) was used and the mixture boiled for 10 minutes: there was left with the sulphur

a small white residue of $PbSO_4$, estimated to contain 5 mgm. Pb, showing that the amount of H_2SO_4 formed increases with the HNO_3 concentration.

Solubility of $PbSO_4$ in Dilute HNO_3. — To 50 and 100 mgm. Pb as $PbSO_4$ in separate experiments 30 ccm. of a mixture of one volume HNO_3 (1.20) and three volumes of water were added and the mixtures heated: the 50 mgm. dissolved in the cold, the 100 mgm. upon boiling.

P. 23, N. 7: Action of HNO_3 on SnS, SnS_2, and Sb_2S_3. — 10 mgm. Sn as SnS and 10 mgm. Sn as SnS_2 were in separate experiments treated by P. 23: there was a white residue in each case. The filtrate was evaporated with H_2SO_4 to slight fuming, diluted, and saturated with H_2S: a yellow precipitate of SnS_2 estimated to contain 0.5 mgm. Sn was formed.

10 mgm. Sb as freshly precipitated Sb_2S_3 were treated by P. 23: the orange color of the sulphides disappeared at once, and a small white precipitate separated, which was estimated to contain 3–4 mgm. Sb. — The experiment was repeated with 5 mgm. Sb: no white residue was left. — The filtrates in these two experiments were made alkaline with NH_4OH: no precipitate of antimony hydroxide separated, even on standing.

P. 24, N. 1: Behavior of HgS, PtS_2, Au, and Metastannic Acid towards Bromine Solution. — 100 mgm. Hg and 500 mgm. Hg as precipitated HgS were warmed slightly in a covered casserole with 30–40 ccm. saturated Br_2 solution: the 100 mgm. dissolved completely, and about three-fourths of the 500 mgm. dissolved. The latter was treated with another portion of bromine water: the residue became nearly white, but blackened slightly when treated with ammonium sulphide.

The experiment was repeated with 10 mgm. Sn as metastannic acid, obtained by treating SnS with dilute HNO_3 by P. 23, the solution was boiled, filtered, and saturated with H_2S: scarcely any precipitate of SnS_2 was formed. — That even small quantities of Au and PtS_2 dissolve in bromine solution is shown by the results of Test Analyses, Nos. 106–113.

P. 24, N. 2: Reduction of Hg_2Cl_2 by $SnCl_2$. — To 1 mgm. Hg as $HgCl_2$ in 20 ccm. water one drop $SnCl_2$ solution (1 % Sn) was added: a nearly white precipitate formed at once. One or two drops more $SnCl_2$ were added: the precipitate darkened rapidly. — The experiment was repeated, except that 0.3 to 0.5 ccm. HCl (1.12) was added to the $HgCl_2$ solution before the $SnCl_2$: a precipitate formed, which remained white for some minutes, even after the addition of several drops of $SnCl_2$ solution.

P. 24, N. 3: Oxidation of Mercurous Salts by HNO_3. — See Part I, C. E., P. 3, N. 7.

P. 24, N. 4: Color of Dilute Solutions of Gold and Platinum. — 1 mgm. Au as $AuCl_3$ and 1 mgm. Pt as H_2PtCl_6 were added in separate experiments to 20 ccm. water and boiled: the solutions had a very pale yellow color, but this color was distinct. A few drops of bromine water were added, and

the solutions were boiled to expel the bromine: the yellow color was more distinct than before.

**P. 24a, N. 1: Detection of Gold, Platinum, and Mercury in the Presence of Each Other.* — Mixtures of elements as shown below dissolved in a little dilute HCl were treated by *P. 24*a*; and the tests, recorded as in the Test Analyses, resulted as follows:

Pt	0 —	0 —	1 S	50 S
Au	10 S	1 S	1 S	0 —
Hg	1 S	200 S	200 —	1 S

P. 25, N. 1: Separation of Metastannic Acid from HgS. — See Test Analyses. Nos. 10–20.

P. 26, N. 1: Solubility of $PbSO_4$ in Water and H_2SO_4. — According to Böttger (*Z. phys. Chem.*, **46**, 604. 1903), 10 ccm. of the saturated solution in water at 25° contain about 0.3 mgm. Pb. — For its solubility in concentrated H_2SO_4 of different strengths, see Comey, *Dictionary of Solubilities*, p. 436.

To determine at what concentration of H_2SO_4 the precipitation was nearly complete, several 2 mgm. portions of Pb as $Pb(NO_3)_2$ were evaporated to fuming with 5 ccm. H_2SO_4 (1.84), and the clear solutions obtained were poured into varying amounts of water; the mixtures were cooled, shaken, allowed to stand for a few minutes, filtered, made alkaline with NH_4OH, and treated with H_2S: with 10, 15, and 20 ccm. water, the final alkaline solution remained almost colorless when treated with H_2S, thus showing that the amount of lead remaining in the filtrate was scarcely appreciable; when as much water as 50 ccm. was used, the liquid was much darkened by H_2S and a small precipitate of PbS separated on standing.

Influence of HNO_3 on the Solubility of $PbSO_4$. — See C. E., P. 23, N. 6.

To each of several solutions containing 1 mgm. Pb as $Pb(NO_3)_2$ in 5 ccm. HNO_3 (1.20) and 15 ccm. water were added 2 ccm. of H_2SO_4 (1.84); the mixture was shaken violently and allowed to stand: only in one or two cases did a precipitate of $PbSO_4$ separate within 10 minutes. 3 ccm. more H_2SO_4 were then added to the solutions that remained clear: $PbSO_4$ precipitated in every case. — The experiment was repeated, except that 2 mgm. Pb were taken: a precipitate of $PbSO_4$ separated when the 2 ccm. H_2SO_4 were added. — To 1 or 2 mgm. Pb in 10 ccm. HNO_3 (1.20) and 10 ccm. water 2 ccm. H_2SO_4 were added: no precipitate resulted. 3 ccm. H_2SO_4 more were added: when 2 mgm. Pb were present, a precipitate formed. — The last experiment was repeated with 4 mgm. Pb, using 2 ccm. H_2SO_4 (1.84): a precipitate of $PbSO_4$ separated.

P. 26, N. 2: Separation of Bismuth from H_2SO_4 Solutions. — 500 mgm. Bi as nitrate were evaporated to fuming with 5 ccm. H_2SO_4 (1.84) and cooled: a large quantity of a white solid separated. The mixture was added to 20 ccm. cold water and cooled: almost all dissolved, only a very small white residue (2–3 mgm.) being left, which was proved by P. 14 not to be $PbSO_4$; but on standing overnight a large, coarsely crystalline white precipitate (probably bismuth oxysulphate) separated. This was filtered off and the filtrate made alkaline with NH_4OH: a precipitate estimated to contain 40–80 mgm. Bi separated. In another experiment the filtrate, instead of being treated with NH_4OH, was diluted with two volumes of water and allowed to stand: more of the precipitate separated slowly. — The experiment was repeated, except that the clear solution obtained on dilution with cold water was heated to boiling: a large white precipitate separated at once, which was similar in appearance to that obtained in the former experiment; this did not dissolve when the solution was cooled and shaken. — Separate portions of the white precipitates which had separated in the preceding experiments from the dilute H_2SO_4 solution on standing, and on heating, were treated with 30–40 ccm. cold H_2SO_4 (1.20): the precipitates dissolved only slightly, even on standing. The undissolved precipitates still containing about 300 mgm. Bi were collected on filters and about 10 ccm. HCl (1.12) poured over each: clear solutions were quickly obtained.

P. 27, N. 1: Nonprecipitation of Small Quantities of Antimony by NH_4OH. — Compare C. E., P. 23, N. 7.

10 mgm. Sb as $SbCl_3$ and 2 ccm. H_2SO_4 (1.84) were added to 10 ccm. water; the mixture was evaporated to fuming, cooled, diluted to 15 ccm., made just alkaline with NH_4OH, and allowed to stand for 30 minutes: no precipitate separated; but when 10 ccm. more NH_4OH (0.96) were added, a very slight white precipitate separated. — The experiment was repeated, except that the $SbCl_3$ solution was first warmed with HCl + HNO_3 to convert it into the antimonic state: no precipitate separated from the NH_4OH solution, even on standing.

P. 27, N. 2: Complex Copper-Ammonia and Cadmium-Ammonia Cathions. — See Dawson and McCrae, *J. Chem. Soc.*, 77, 1239 (1900); Euler, *Ber. d. chem. Ges.*, 36, 3400 (1903); Bonsdorff, *Z. anorg. Chem.*, 41, 132 (1904); Locke and Forssell, *Am. Chem. J.*, 31, 268 (1904).

P. 28, N. 1: Precipitation of BiOCl. — To 0.25 ccm. HCl (1.20) was added 1 mgm. Bi as chloride, and the solution poured into 100 ccm. water at 60°: a precipitate of BiOCl appeared in about a minute. After 5 minutes the solution was filtered, made alkaline with NH_4OH, and treated with H_2S: no precipitate formed. — The experiment was repeated, using 0.5 ccm. HCl (1.20) instead of 0.25 ccm.: no precipitate of BiOCl formed in 5 minutes. — It was again repeated, using 0.5 ccm. HCl and 2 mgm. Bi: a

precipitate of Bi had formed after 5 minutes, but the filtrate also gave a precipitate with H_2S. — It was again repeated, using 1 ccm. HCl (1.20) and 6 and 8 mgm. Bi: with 8 mgm. Bi a precipitate formed, but not with 6 mgm.

In a number of experiments 1 mgm. Bi dissolved in 0.25 ccm. HCl (1.20) was poured into 100 ccm. water at various temperatures: a precipitate of BiOCl appeared in less than 1 minute when the temperature was 55°, 70°, 80°, or 90°, in about 2 minutes at 45°, in about 5 minutes at 25°, and only after 10–15 minutes at 15°.

P. 28, N. 2: Decomposition of Sodium Stannite Solution. — A sodium stannite solution was prepared as directed and kept in a stoppered bottle for a week: a black, crystalline deposit appeared at the bottom of the bottle.

P. 28, N. 3: Action of Sodium Stannite on BiOCl. — Vanino and Treubert (*Ber. d. chem. Ges.*, 31, 1113. 1898) have shown that the black precipitate formed by the action of a stannite solution is metallic bismuth, and not BiO, as was formerly supposed to be the case.

0.5 mgm. Bi as $BiCl_3$ was added in one experiment to 100 ccm. water, and in a second one to 500 ccm. water; the precipitate formed (which was scarcely visible in the second case) was collected on a filter, washed with water, and then treated with Na_2SnO_2: the greater part of the filter was at once blackened.

10 mgm. Pb as $Pb(OH)_2$ were treated on a filter first with a cold Na_2SnO_2 solution and then with a solution at about 60°: in the first case no blackening occurred in several minutes, while in the second it occurred almost immediately.

The experiment was repeated with 20 mgm. Sb as antimonous and with 20 mgm. Sb as antimonic hydroxide: no blackening was observed in either case.

The experiment with cold Na_2SnO_2 was repeated with 2 mgm. Fe as $Fe(OH)_3$: the red precipitate did not change color in 10 minutes; but, when hot Na_2SnO_2 was poured over it, it slowly became darker.

P. 29, N. 1: Precipitation of Copper Ferrocyanide in the Presence of a Cadmium Salt. — A solution containing 1 mgm. Cu as $CuSO_4$, 500 mgm. Cd as $Cd(NO_3)_2$, and 2 ccm. H_2SO_4 (1.84) was made alkaline with NH_4OH: the solution remained colorless. One-fourth of the solution (about 10 ccm.) was acidified with acetic acid and two drops of a 4% $K_4Fe(CN)_6$ solution added: a white precipitate separated, which had at first only a slight pink tinge, but this color deepened and was very apparent after 10 minutes. Excess of $K_4Fe(CN)_6$ was then added: much more of the white precipitate separated, and the pink color of the copper salt was almost obscured. — The experiment was repeated, except that only 0.5 mgm. Cu was taken: the result was exactly the same, thus showing that this test is a very deli-

cate one, provided only two to three drops of $K_4Fe(CN)_6$ solution are first added.

P. 29, N. 2: Precipitation of Molybdenum by Potassium Ferrocyanide. — 1 and 100 mgm. Mo as MoO_3, and 1 and 10 mgm. U as $UO_2(C_2H_3O_2)_2$, in separate experiments were dissolved in 2 ccm. NH_4OH (0.96), the solutions made acid with acetic acid, and several drops of $K_4Fe(CN)_6$ solution added: no change was observed. — The experiments were repeated, except that the NH_4OH solution was acidified with HCl instead of with acetic acid: with the 100 mgm. Mo and the 10 mgm. U a large dark red precipitate separated at once: with the 1 mgm. portions a deep red solution was obtained, from which a dark red precipitate separated after a minute or two.

P. 30, N. 1 and 2: Complex Cuprocyanide and Cadmicyanide Anions. — See Euler, *Ber. d. chem. Ges.*, 36, 3404 (1903); Bodländer, *Ber. d. chem. Ges.*, 36, 3933 (1903).

P. 30, N. 3: Behavior of Mercury, Lead, and Bismuth in the Cadmium Test with H_2S. — 1 mgm. Hg, 1 mgm. Pb, and 1 mgm. Bi were treated in separate experiments by P. 26, 27, and 30, filtering immediately after the addition of H_2SO_4 and of NH_4OH: there resulted a precipitate with H_2SO_4 in the case of lead and with NH_4OH in the case of bismuth, but none in the case of mercury with these reagents. With H_2S in the KCN solution small dark brown precipitates formed in the lead solution and in the mercury solution, and a very small black one in the bismuth solution. — The experiment was repeated with 150 mgm. Pb and with 150 mgm. Bi, the precipitates of $PbSO_4$ and of $(BiO)_2SO_4$ and $Bi(OH)_3$ being filtered after cooling and standing a few minutes: even less precipitate resulted in each case than when only 1 mgm. was used.

Separation of CdS from Black Sulphides by Dilute H_2SO_4. — 1 mgm. Cd as CdS, freshly precipitated by H_2S from an NH_4OH solution, was boiled gently for about 5 minutes with 20 ccm. of a mixture of one volume of H_2SO_4 (1.20) with four volumes of water; the solution was filtered, diluted with two to three times its volume of water, and saturated with H_2S in the cold: a yellow precipitate of CdS separated.

The experiment was repeated, except that in separate experiments 1 mgm. Cu, 1 mgm. Pb, and 1 mgm. Hg were mixed with 1 mgm. Cd: a distinctly yellow precipitate was obtained in each experiment.

About 50 mgm. Cd as CdS were boiled for 5 minutes with 20 ccm. of a mixture of one volume H_2SO_4 (1.20) and four volumes of water: the sulphide did not dissolve completely.

Analysis of the Tin Group

P. 41, N. 1: Detection of the Tin Group by the Appearance of the HCl Precipitate from the Ammonium Polysulphide Solution. — Separate 10 ccm.

portions of the ammonium polysulphide reagent (see P. 41, N. 2) were diluted to known volumes in some experiments with hot water, and in others with cold water; the solutions were then made acid by adding HCl slowly, and the mixtures were shaken and allowed to stand: from cold solutions of a total volume of 30 to 50 ccm. the sulphur separated as a pure white, finely divided precipitate, which coagulated slowly on shaking, and had then only a faint yellow tinge which did not change on warming. From more concentrated solutions, and especially from hot solutions, the yellow color after coagulation was more pronounced. Separate 10 ccm. portions of the ammonium polysulphide reagent containing 1 mgm. As were diluted with 20 ccm. and with 40 ccm. water; HCl was slowly added until the solutions were acid; the mixtures were shaken and allowed to stand: the precipitate had at first the appearance of pure sulphur, but it coagulated more quickly, became flocculent, and turned brilliant yellow. Further experiments showed that the coagulation and change of color took place more quickly when the mixture was slightly warmed after coagulation. — The experiment was repeated, using 1 mgm. Sb instead of As: the HCl precipitate remained white as long as the solution remained alkaline, but on further addition of HCl the orange color of the Sb_2S_5 became very apparent; the precipitate quickly coagulated and became flocculent. — The experiment was repeated with 1 mgm. Sn: the HCl precipitate had a very faint yellow tinge; it coagulated only slowly, and appeared like the pure sulphur precipitate, except that it had a much darker yellow color. The experiment was repeated with 1 mgm. Cu as $CuSO_4$: a dark orange-yellow (liver-colored) precipitate was obtained. — The experiment was repeated with 1 mgm. Hg as $HgCl_2$: the HCl precipitate was nearly white, but when warmed slightly it became dark gray in color.

Color of a Mixture of Tin and Antimony Sulphides. — 500 mgm. Sn as $SnCl_2$ and 200 mgm. Sb as $SbCl_3$ were slowly added to 10 ccm. of a warm ammonium polysulphide solution, and the clear solution obtained was at once acidified with HCl: a brown precipitate separated, which slowly became dark gray in color. — The experiment was repeated, except that the ammonium polysulphide solution was cooled and diluted to about 40 ccm. and HCl was slowly added: the precipitate was at first yellow with an orange tint, but on standing it slowly became darker, assuming first a brown and finally a dark gray color. — These precipitates were treated by P. 42–47: the antimony and tin dissolved completely in HCl (1.20) (P. 42), and the antimony was completely precipitated in P. 45 as an orange precipitate.

P. 41, N. 2: Solubility of Tin-Group Sulphides in NH_4OH. — See C. E., P. 22, N. 1.

For evidence that salts of intermediate sulpho-oxyacids of arsenic are formed when As_2S_5 is dissolved in an alkali, see McCay, *Ber. d. chem. Ges.*,

32, 2471 (1899); *Z. anorg. Chem.*, 25, 459 (1901); McLouchlan, *Ber. d. chem. Ges.*, 34, 2166 (1901); Weinland and Lehman, *Z. anorg. Chem.*, 26, 322 (1901). Treadwell (*Qual. Anal.*, p. 188. 1902) concludes that K_3SbO_3 is not formed by the action of KOH on Sb_2S_3 according to the equation $Sb_2S_3 + 6KOH = K_3SbO_3 + K_3SbS_3 + 3H_2O$, because this solution is stable when diluted, while a solution of K_3SbO_3 is not.

For evidence that the precipitation of arsenic is incomplete when a solution of As_2S_5 in an alkali is made acid, see Weinland and Lehman, *loc. cit.*, and Vanino and Griebel, *Z. anal. Chem.*, 40, 589 (1901).

Presence of Copper and Mercury in the Tin Group. — For the solubility of CuS and HgS in NH_4OH and in ammonium mono and polysulphide, see C. E., P. 22, N. 4. — For the fact that copper and mercury will divide in the heating with HCl (1.20), see C. E., P. 42, N. 6. — That the presence of even 2 mgm. Cu or of Hg does not interfere with the detection of arsenic is shown in C. E., P. 43, N. 3. — That the same amount of copper or mercury does not prevent the detection of antimony is shown in C. E., P. 46, N. 1.

P. 42, N. 1: Solubility of Sb_2S_5 in HCl (1.20). — 500 mgm. Sb as sulphide, freshly precipitated from an ammonium polysulphide solution, and therefore consisting mainly of Sb_2S_5, were treated according to the procedure: nearly all the antimony dissolved, but the sulphur residue had an orange-red color. The residue was treated a second time in the same way, and the HCl solution diluted and saturated with H_2S: a small precipitate of Sb_2S_3 estimated to contain 1 or 2 mgm. Sb formed. The sulphur residue was again treated with HCl: scarcely any Sb dissolved, although the residue still had a distinct orange color.

A mixture of 1 mgm. Sb as Sb_2S_5 with 500 mgm. As as As_2S_5 (freshly precipitated from an ammonium polysulphide solution and carefully dried by suction) was treated by the procedure, and the residue subjected to a second and then to a third treatment; the separate HCl solutions were diluted and treated with H_2S by P. 45: the first solution contained about 0.6 mgm. Sb, the second about half this amount, and the third only a trace. — This experiment was repeated, except that the sulphides were not carefully dried before adding HCl (1.20): the second HCl solution contained more Sb than the first, thus showing that the presence of water interferes with the action of the HCl.

Formation of $SbCl_3$ by Dissolving Sb_2S_5 in HCl. — See Classen and Bauer, *Ber. d. chem. Ges.*, 16, 1067 (1883).

P. 42, N. 2: Solubility of As_2S_5 in HCl (1.20). — Seven different 500 mgm. portions of As as As_2S_5, freshly precipitated from an ammonium polysulphide solution, were treated by the procedure; and the filtrates were warmed and saturated completely with H_2S: only a faint precipitate resulted, in no case corresponding to more than a small fraction of a milligram of

arsenic. — The experiment was repeated, except that the HCl (1.20) was boiled gently for 5 minutes: the filtrate was found to contain 5–10 mgm. As. The vapors given off blackened lead acetate paper held above the flask.

P. 42, N. 3: Solubility of As_2S_3 in HCl (1.20). — Six separate 500 mgm. portions of As as As_2S_3, freshly precipitated from H_3AsO_3 solution by H_2S in five of the experiments and by acidifying a solution of As_2S_3 in NH_4OH in the remaining one, were treated by the procedure and the filtrate saturated with H_2S: in each experiment distinct precipitates of As_2S_3 were obtained, which were estimated to contain between 1 and 5 mgm. As. — The experiments were repeated, except that a slow current of H_2S was passed through the HCl during the experiment: the filtrates then gave with H_2S scarcely any precipitate — A solution of 100 mgm. As as As_2O_3 in 20 ccm. HCl (1.20) was saturated with H_2S for 5 minutes at about 90°, the solution decanted off, water added, and H_2S again passed in: no more precipitate separated.

P. 42, N. 6: Solubility of CuS and HgS in HCl. — 10 mgm. Cu as CuS and 10 mgm. Hg as HgS, freshly precipitated, were treated in separate experiments by P. 42: the greater part but not all of each of the precipitates was dissolved.

**Solubility of TeS_2 in HCl (1.20).* — 50 mgm. Te as TeO_2 dissolved in HCl were added to 10 ccm. ammonium polysulphide; the solution was treated by P. 41, the black HCl precipitate was heated with HCl (1.20) by P. 42, and the filtrate was saturated with H_2S: a precipitate formed estimated to contain about 1 to 2 mgm. Te. — The experiment was repeated, except that the HCl solution was kept saturated with H_2S: in this case no tellurium dissolved.

**Insolubility of Sulphides of Pt, Au, Se, and Mo in HCl (1.20).* — 20 mgm. Pt, 10 mgm. Au, 50 mgm. Se, and 50 mgm. Mo, all as sulphides precipitated by acidifying an ammonium polysulphide solution, were in separate experiments digested at about 90° for 10 minutes with 10 ccm. HCl (1.20), diluted, and filtered, as described in P. 42; the filtrates were saturated with H_2S at 100°, diluted to 50 ccm., again heated and saturated with H_2S: no precipitate separated in any case, not even after several minutes, thus showing that nothing had dissolved in the HCl.

P. 43, N. 1: Reactions between $HClO_3$ and HCl. — See Schacherl, *Liebig's Ann. Chem.*, **182**, 193 (1876); Bray, *Z. anorg. Chem.*, **48**, 242 (1906).

P. 43, N. 2: Nonexistence of $AsCl_5$. — See Smith and Hora, *J. Am. Chem. Soc.*, **26**, 632 (1904). For earlier references, see Baskerville and Bennet, *J. Am. Chem. Soc.*, **24**, 1070 (1902).

Non-volatility of Arsenic Acid from HCl Solution. — 2.0 grams As as As_2O_5, containing a small amount of As_2O_3, were dissolved in 20 ccm. HCl (1.20)

and distilled until only half the volume remained in the flask: 10 ccm. more of HCl (1.20) were added and the solution distilled as before; and this operation was repeated several times: the distillates were collected in separate portions of cold water and saturated with H_2S: in the first distillates yellow precipitates appeared at once, which decreased in amount from about 15 mgm. As in the first distillate to about 0.5 mgm. As in the fifth. (This was evidently due to the As_2O_3 present as impurity.) These solutions were filtered and the filtrates treated at 90° with H_2S for several minutes: very little, if any, precipitate was obtained, showing that arsenic in the higher state of oxidation was practically absent. From later distillates precipitates containing about 0.5 mgm. As separated quickly with H_2S in the cold, and no further precipitate separated when the solutions were heated and treated with H_2S. Thus even from this concentrated solution of arsenic acid in the presence of concentrated HCl only a trifling amount of arsenic volatilized. Since the higher halogen compound of an element is in general more volatile than the lower, it is therefore highly probable, from the above result, that $AsCl_5$ is not present even in concentrated HCl solution.

P. 43, N. 3: Non-influence of Mercury, Antimony, or Tin on the Test for Arsenic with $MgCl_2$. — 2 mgm. Hg as $HgCl_2$, 2 mgm. Sn as $SnCl_4$, 2 mgm. Sb as Sb_2S_3 were treated in separate experiments according to the procedure: with mercury a precipitate was obtained with NH_4OH, and the filtrate when acidified with HCl and treated with H_2S gave no precipitate; with tin and antimony no permanent precipitate formed in the NH_4OH solution, nor was one formed with $MgCl_2$ and NH_4Cl.

P. 43, N. 4: Delicacy of Test for Arsenic. — 0.5, 1, and 2 mgm. As as H_3AsO_4 were treated in separate experiments according to P. 43, the final volume being in each case about 5 ccm.: with 2 mgm. the $MgNH_4AsO_4$ precipitate appeared immediately upon shaking; with 1 mgm., after gentle stirring; and with 0.5 mgm., slowly after rubbing with a glass rod for a minute or two.

**P. 43a, N. 2: Action of KI on K_2PtCl_6.* — To 5 mgm. Pt as H_2PtCl_6 were added 10 ccm. water and a few drops KI solution: a deep red solution resulted. 5 ccm. CS_2 were added and the mixture shaken: the water layer remained dark red, and the CS_2 solution was colored slightly, owing to the presence of a trace of iodine. The water layer was shaken with a fresh portion of CS_2: this time the CS_2 layer was colorless, thus proving that only an insignificant quantity of iodine was present, and therefore that the platinic compound is not reduced. To the solution some H_2SO_3 solution was added: the color of the solution changed at once to a pale yellow.

**P. 43b, N. 1: Action of Oxalic Acid on Solutions of Chlorauric, Selenous, Tellurous, and Molybdic Acids.* — 2 mgm. Au as $AuCl_3$ were dissolved in one experiment in a dilute HCl solution containing about 0.5 gram $H_2C_2O_4$, in

a second one in a dilute solution of NH_4OH and $(NH_4)_2C_2O_4$, and the solutions were evaporated to 3–4 ccm.: no precipitate separated in either case. The solutions were then evaporated almost to dryness to expel the excess of HCl and of NH_4OH, were diluted to about 15 ccm., and again boiled: a purple precipitate of gold quickly appeared in both cases. — In another experiment 0.5 mgm. Au as $AuCl_3$ was added to 10 ccm. of a dilute $(NH_4)_2C_2O_4$ solution which had been made slightly acid with $H_2C_2O_4$, and the solution was heated to boiling: a purple precipitate of gold separated.

5 mgm. Au as $AuCl_3$ were treated according to the procedure: a precipitate of gold appeared quickly and continued to separate for 2 or 3 minutes. After about 5 minutes the gold was filtered off and the filtrate again digested for several minutes on the steam bath: no further precipitate of gold separated.

50 mgm. Se as H_2SeO_3, 50 mgm. Te as H_2TeO_3, and 50 mgm. Mo as $(NH_4)_2MoO_4$ were treated in separate experiments by *P. 43*b*: in the case of tellurium a white precipitate separated from the $H_2C_2O_4$ solution on evaporation, but it dissolved readily on adding HCl; in the other two experiments no precipitate formed and no color change was noticed.

**P. 43*c*, N. 1: Action of H_2SO_3 on H_2SeO_3.* — 1 mgm. Se as SeO_2 in 10 ccm. HCl (1.15) was saturated with SO_2 gas at room temperature: a red precipitate appeared at once and continued to increase slowly. After 5 minutes the solution was filtered and the filtrate allowed to stand: it remained clear. — The experiment was repeated, except that the solution was saturated at 90°: a reddish precipitate appeared at once, but it changed rapidly to a very compact, nearly black precipitate that collected at the bottom of the test tube. — The first experiment was repeated with 0.5 mgm. Se: a considerable red precipitate separated within 5 minutes.

**P. 43*c*, N. 2: Action of H_2SO_3 on H_2TeO_3.* — 100 mgm. Te as TeO_2 were dissolved in separate experiments in 10 ccm. HCl (1.20), in 10 ccm. HCl (1.20) and 5 ccm. water, and in 20 ccm. HCl (1.12). Each solution in a test tube was saturated with SO_2 gas, was allowed to stand 5 minutes, and then placed in a steam bath at 100° for 15 minutes: no precipitate of tellurium was formed in any case. Enough water was added to make the volume 30 to 40 ccm.: a black precipitate of tellurium appeared at once.

In each of eight test tubes were placed 0.5 mgm. Te as TeO_2 and 25 ccm. saturated H_2SO_3 solution. To the first of these were added 3 ccm. 40% HCl, to the second 4 ccm., to the third 5 ccm., and so on up to the eighth, which contained 10 ccm.; the tubes were then all heated in a steam bath: those with 3 and 4 ccm. HCl gave scarcely any precipitate; in the others the quantity of precipitate increased with the increase of acid up to 7 ccm., and then decreased steadily with further increase in the amount of HCl.

**P. 43*d*, N. 1: Action of KI and of KI + H_2SO_3 on Tellurium*

Solutions. — For the formation of TeI_4 in the reaction between H_2TeO_3 and KI, see Gooch and Morgan, *Am. J. Sci.* (4), **2**, 271 (1896). For the formation of K_2TeI_6, see Wheeler, *Am. J. Sci.* (3), **45**, 267 (1893). For its deep red color, see Norris and Fay, *Am. Chem. J.*, **23**, 109 (1900).

To prove that tellurium itself and not an iodide of it is precipitated by H_2SO_3 and HI, 20 mgm. Te as TeO_2 were dissolved in 10 ccm. HCl (1.12) and 1 mgm. I as KI and a little solid Na_2SO_3 were added: a large black precipitate formed slowly. This was filtered off after half an hour, the filtrate was diluted to 20 ccm., and to it were added a few drops KI solution and a little solid Na_2SO_3: a black precipitate estimated to contain only 1 to 2 mgm. Te resulted. — The experiment was repeated, except that the mixture was allowed to stand overnight before filtering: only about 0.2 mgm. Te remained in solution.

To determine the proper concentration of HCl for the complete precipitation of the tellurium, a few drops of KI solution were added to solutions containing 0.5 mgm. Te as TeO_2 dissolved in 10 ccm. HCl (1.20), in 15 ccm. HCl (1.15), in 20 ccm. HCl (1.12), and in 30 ccm. HCl (1.06), respectively: a deep red color resulted in each case, but was less intense in the most concentrated and in the most dilute HCl than in the other two solutions. A crystal of Na_2SO_3 was added to each solution: no change was observed in the three more concentrated HCl solutions, but a black precipitate of tellurium formed in the most dilute solution. — In another experiment 0.1 mgm. Te was dissolved in 20 ccm. HCl (1.06), and a drop of KI and a crystal of Na_2SO_3 added: a black precipitate resulted.

50 mgm. Te as TeO_2 were treated according to the procedure, and the precipitated tellurium filtered off after 5 minutes: the filtrate had a strong odor of SO_2, but no more tellurium separated in half an hour, even when a little KI was added.

P. 43d, N. 2: Action of HI on H_2SeO_3.* — See Norris and Fay, *Am. Chem. J.*, **23, 109 (1900).

**P. 43d, N. 3: Action of HI on H_2MoO_4.* — To separate solutions of 50 mgm. Mo as MoO_3 in 10 ccm. HCl (1.20) and in 20 ccm. HCl (1.12) a few drops of KI solution were added: iodine was slowly liberated in both cases, but more rapidly in the more strongly acid solution.

**P. 43e, N. 2: Action of Zinc and KCNS on H_2MoO_4.* — To 1 mgm. Mo as MoO_3 dissolved in 20 ccm. HCl (1.06) in a test tube were added a crystal of KCNS and some granules of zinc: a brilliant red color appeared very quickly and remained unchanged for about 5 minutes; the color slowly changed to yellow, and then faded until after about half an hour the solution was nearly colorless. — The experiment was repeated, except that the KCNS was not added until after the action of the zinc had continued for 15 minutes: a yellow color resulted. — The experiment was repeated, except

that the KCNS was added after about an hour: the solution remained colorless.

For the composition of the red compound produced with KSCN and zinc, see Sand and Burger, *Ber. d. chem. Ges.*, 38, 3384 (1905); 39, 1761 (1906).

P. 44, N. 1 and 2: Action of H_2S on H_3AsO_4 Solutions. — See McCay, *Am. Chem. J.*, 10, 459 (1888). Brauner and Tomicek, *J. Chem. Soc.*, 53, 145 (1888). Usher and Travers, *J. Chem. Soc.*, 87, 1370 (1905).

P. 45, N. 1: Separation of Antimony and Tin by H_2S. — Known amounts of Sb and Sn as chlorides were added to an ammonium polysulphide solution and precipitated as Sb_2S_5 and SnS_2 with HCl; the precipitates were dried by suction and digested with 10 ccm. HCl (1.20) at 90° for 10 minutes in a 50 ccm. conical flask. Each solution so obtained was diluted to a known volume and treated with H_2S just below the boiling point. The volume of the diluted solution at which the precipitation of Sb_2S_3 was nearly or quite complete and that at which the precipitation of SnS_2 began and became considerable are given in the following table:

Experiment No.	Sn	Sb	Volume of solution at which precipitation of antimony was nearly complete.	Volume of solution at which precipitation of antimony was complete.	Volume of solution at which precipitation of tin began.	Volume of solution at which precipitation of tin was considerable.
	mgm.	mgm.				
1	500	0	. .	. .	50	60
2	500	0	. .	. .	60	70
3	400	1	40	50	60	70
4	500	1	. .	50	60	70
5	500	1	. .	55	60	70
6, 7	500	200	40	50	60	70
8	10	500	40	50	. .	. .
9	200	200	. .	50	. .	. .
10	0	1	. .	55	. .	. .

In Experiment No. 1 a slight yellow precipitate of SnS_2 appeared in testing for antimony, but a good blank was obtained in No. 2. In Experiment 4 an orange-red precipitate of Sb_2S_3 was obtained; in Experiment 5 a dark-colored precipitate, which gave a good confirmatory test for antimony. In Experiment 10 the Sb_2S_3 precipitate did not separate until the last 5 ccm. of water were added.

P. 45, N. 2: Precipitation of CuS and HgS from HCl Solution. — 1 mgm. Cu and 0.5 mgm. and 4–5 mgm. Hg as chlorides were added in separate experiments to 10 ccm. HCl (1.20) and 40 ccm. H_2O, and the solutions were

heated to boiling and saturated with H_2S at 90°: in the first two cases light gray precipitates formed slowly, which on the filter appeared to be black; in the last case a black precipitate. The precipitates were filtered out, the solutions diluted and treated with H_2S: in the mercury experiments they gave no precipitates, but in the case of Cu a very slight precipitate formed.

P. 46, N. 1: Influence of Copper and Mercury on the Reduction Test for Antimony. — 1 and 2 mgm. Hg as HgS and 1 and 2 mgm. Cu as CuS were treated in separate experiments according to P. 46: the mercury separated on the platinum as a gray, loosely adhering film, the copper as a red, metallic, firmly adhering deposit, which could not be mistaken for antimony.

The experiments were repeated in the presence of 0.5 and 1 mgm. Sb: characteristic black deposits of Sb were obtained.

P. 46, N. 2: Behavior of Arsenic and Tellurium in the Reduction Test for Antimony. — 1, 4, and 10 mgm. As as H_3AsO_4 and 0.5 mgm. Te as H_2TeO_3 were treated in separate experiments according to P. 46: with the 10 mgm. As and with the tellurium black deposits on the platinum were obtained, which dissolved readily in a normal, cold alkaline solution of NaOCl; no deposit of arsenic was obtained with the 1 or 4 mgm. As. It is therefore improbable that a black deposit of arsenic will ever be obtained in an actual analysis, since only very small amounts will be dissolved in the HCl treatment (P. 42).

Insolubility of Sb in NaOCl. — 1 mgm. Sb precipitated on platinum foil by the action of HCl and Sn was treated in the cold for 5–10 minutes with a normal, alkaline NaOCl solution: no change took place.

P. 47, N. 1: Effect of Temperature on the Precipitation of SnS_2. — A solution of 1 mgm. Sn as $SnCl_4$ in 10 ccm. HCl (1.20) was successively diluted with portions of water and saturated with H_2S at 90° after each dilution: a precipitate formed only when the volume of the solution had become 110–120 ccm. — The experiment was repeated several times, except that the solutions were saturated for 5–10 minutes with H_2S at 20°: a precipitate formed when the volume became 60–70 ccm.

P. 47, N. 2: Delicacy of Confirmatory Test for Tin. — 0.5 Sn as $SnCl_4$ was treated in several experiments according to P. 47: in all cases a precipitate of SnS_2, and in most cases one of Hg_2Cl_2, was obtained.

THE PRICE OF ELECTRICITY[1]

BY ROBERT SEVER HALE

I FEEL a little diffidence in addressing engineers on the subject of prices as distinct from the subject of costs. A reduction in costs, even if it does not lead to a reduction of prices, is always of benefit to somebody, and is of interest to engineers since it is always in the end for the general good. On the other hand, the question of prices may be and often is merely a commercial question between buyer and seller; nevertheless there are cases in which a scientific system of prices enables a lower price to be made to the purchaser without reducing the seller's gain, and the study of such a system comes easily within the well-known definition of an engineer as a man who can do for one dollar what any fool can do for two.

The question of prices depends very largely, of course, on costs, and in the following discussion I shall have occasion to refer frequently to the costs of the Boston Edison Company, since I shall devote my attention almost exclusively to the prices of that company. The electric light companies of this state are, as you know, under the control of the Gas Commission and make very full reports to that commission, in addition to which all the financial and engineering operations of the companies are open to the inspection of the commission. Out of the reports to the commission the latter makes public only some of the figures; and since it would be obviously improper for me to make public what the commission does not, I wish it clearly understood that in the following discussion any figures that are not taken from the Gas Commission report are used for illustration merely and do not represent actual results.

Beginning now with the total costs, the total costs for a year are

[1] An address delivered before the Senior Class in Electrical Engineering of the Massachusetts Institute of Technology, in May, 1905, and May, 1906.

Since the above was written the Edison Company has made changes and reductions in its rates, particularly to its small consumers; but these changes affect only the figures and not the principles.

easily taken from the report; and for the report of the year covered by the last published report of the commission the total income of the Boston Edison Company was $2,700,000, which just paid all the cash outlay, a small depreciation charge, and a net dividend of 5 per cent. on the $200 per share paid in on the stock. In other words, $2,700,000 was the total cost of the current sold and service rendered by the Boston Edison Company; and if a single payment were to be made for the current and service, the proper price would have been, as it was, $2,700,000. The question of the total cost is simple, and the question of the total of the prices is likewise simple; it is the question of the division of the amount among the different customers that constitutes the price question. The solution from a scientific point of view is for an electric company simpler than for most businesses, as may be brought out by a homely though amusing illustration.

Suppose a farmer buys a calf for $9, spends $1 worth of his time in killing and skinning it, and then starts to figure out what is the proper price at which he should sell the veal and the price at which he should sell the hide. The farmer does not have to consider the question from a scientific point of view. He merely sells the hide and the veal for what he can get, and for the most he can get; and if he could get $15 for the hide and $20 for the veal, he would take them without a qualm of conscience or any idea that the commissioner of agriculture might hold a hearing as to reducing his prices or determining the fair market value of his farm. Public service corporations, however, receive a limited monopoly from the public, and in return for that monopoly are expected to sell what corresponds to their veal and hide at fair prices. It should be noted, however, that this requirement of fair prices should extend only to the extent of the monopoly granted. If a public service corporation has two products, in respect of only one of which it is granted a monopoly, then the public has a right to control only the prices of the monopolized product, and in respect of the product for which the public grants no monopoly the public has no right to determine prices. This rule, of course, is clear.

Returning now to the Boston Edison Company, the total cost of its current and service was $2,700,000, and the $2,700,000 received was a fair price; but not only is it necessary that the total price should be a fair one, but it is also necessary that the division of the price among the different customers should be a fair one. In fact, this is the most necessary feature, since it does not affect a business man

very seriously to pay an extra charge of 10 per cent. provided his competitor likewise pays the same extra charge; while if a business man pays only a fair charge, but his competitor gets a 10 per cent. rebate, then the first customer is worse off in spite of the fact that in this case the seller is getting even less than a fair price, while in the other case the seller was getting an unfairly high price.

Now how is the $2,700,000 which it costs the Boston Edison Company to be divided up among its customers? It supplied about 12,600 customers in all, making the average about $200 per customer. It supplied about 900,000 lamps, or their equivalent in other service, making the cost $3 per lamp. It supplied about 25,000,000 kilowatt hours, making the cost about 10 cents per kilowatt hour. While these are the average costs or average prices per customer, per lamp, or per kilowatt hour, it is perfectly clear that we cannot depend solely on averages in any particular case, any more than any of you expect to work for the average earnings per adult male in the state of Massachusetts. The average cost per customer of the Boston Edison Company is about $200, but some customers cost very much more and some very much less. The average cost per lamp is about $3, but some lamps cost much more and some much less. The average cost per kilowatt hour is about 10 cents, but some cost much more and some much less.

Now what is the theory that determines the proper unit of charge for a public service corporation? The earliest public service corporations in the modern sense were probably the toll roads and bridges; the first made a charge varying with the distance traveled and the bridges made a charge depending chiefly on the weight, though both were so arbitrarily made up that no very definite rule can be discovered. The water companies, which were also some of the earliest public service corporations, began by making the charge proportional not to the amount of water or value of service rendered, but proportional to the value of the land or house to which the water was supplied; and while this method has continued even to the present time, the tendency is now in the line of making the water charge proportional to the number of fixtures that can use water and to the quantity of water used. It should be noted, however, that the tendency towards meter rates for water is only in part because this is considered a fair method in itself, but is partly because no other method prevents waste.

The comparison between roads, bridges, and sewers (which are always considered proper subjects of municipal enterprise), water sup-

ply (which is often so considered, but is carried on successfully by private enterprise), gas and electricity (which are usually best done by private enterprise, but occasionally well done by the public), and such enterprises as municipal ice or municipal contracting or municipal houses (which, as we know, have always proved failures) may perhaps indicate a guiding rule. For roads and bridges the public intends that no charge shall be made, but that they shall be free to every one. Under these circumstances they are successfully carried on by the public.

The public intends that every one shall have water, with no charge except such as is necessary to prevent waste. Under these circumstances the work is usually, though not always, well done by the public. The public intends that every one who wants them shall have gas and electricity at a fair price proportional to the cost of the service, and these businesses are occasionally well done by the public. I presume that the public also intends that every one who wants food or houses or clothing shall have them at a fair price; nevertheless the public for some reason does not feel the necessity so strongly as in the case of roads or bridges or water, and the supply of food or clothing has been carried on by municipalities successfully only in times of great stress. In other words, successful instances of municipal management have almost invariably been cases where the municipality wished to supply the product free or at less than cost, as in the cases of bridges and water or of food at times of famine, and the instances of a municipality successfully engaging in genuine trading for profit have been very rare.

This discussion as to the proper limits of municipal trading has taken me away from my subject, which was the question of what is the proper basis or unit of charge for an electric light company. There is no essential reason why either the kilowatt hour or its multiples or submultiples, the lamp hour or horse-power hour, should have been used. The telephone companies and some water companies charge so much per customer, but by a graded differential system they take account of the fact that some customers cost them more than others. In the old days the electric companies charged so much per lamp (usually $12 per annum) and some electric companies and some water companies do so still, the water company's charge being so much per fixture. In all these cases, however, the companies (or municipalities, when the supply was municipal) have by various systems of differential

charge recognized the fact that some telephones or customers or lamps or fixtures cost them more than others.

I will not go into the history and science of electric supply to explain why it is that most electric companies have finally settled on the kilowatt hour or its equivalents — the lamp hour or horse-power hour — as the basis of charge; in fact, I could not, since this has come about more as a matter of growth than from any well-defined plan or reason; but I do wish to state most emphatically that there is just as much reason for differentiating between the kilowatt hours that cost the company 20, 30, and 50 cents each, and even more, and the kilowatt hours that cost the company less than one-half cent each as there is between customers and lamps. We supply some customers at $12 each per annum and charge some customers $40,000 each per annum, and we intend that each of these customers shall give us a fair margin of profit, if we can get it, and shall in no case be supplied at a loss. We supply some lamps at a cost of $1 per annum each, and even less, and get as high as $10 or $15 per annum from others, and again intend that they shall all give us, so far as possible, a fair margin of profit, and that none shall be supplied at a loss. We supply some kilowatt hours at 20 cents and some at 2½ cents; and while we try to get a fair margin of profit on them all to pay our 5 per cent. dividend, yet we actually lose money on a great many of the kilowatt hours we supply at the highest prices.

Now how do we distinguish between the kilowatt hours that cost 20 or 30 cents and those that cost only one-half cent? In the case of a customer we have a definite address or location, and know exactly what happens when he comes on to the system and uses current. In the case of different lamps we know very clearly that to supply one lamp for a year takes only 60 pounds of coal and to supply another over half a ton, so that the first lamp may be supplied at the cost of half a ton of coal cheaper than the second if the other expenses are the same. The kilowatt hour, however, while more exact and definite than the customer or the lamp, is more a definition than a concrete quantity, and the variation in the cost must be considered more carefully.

In the general analysis of rates, which has been my particular work with the Boston Edison Company for the last few months, I have a great many methods of analysis, but I can perhaps make the matter clearer to you in this short talk by explaining what we have been doing lately in the case of a very large customer who was desirous of taking current

from us. This particular customer has the equivalent of 10,000 to 15,000 lamps connected, of which he will probably use about 8,000 at any one time. To supply him, therefore, we shall have to assign about one-tenth of one of our new turbines, together with the proportion of the steam piping, boilers, pumps, condensers, coal handling apparatus, and station building, also switchboard at the L Street Station, high tension cable from L Street Station to switchboard in Boston substation; at this substation storage battery, and underground cable and duct from the substation to this particular customer. In this particular case most of this apparatus has been already ordered in anticipation of the regular growth of business; but when this customer comes on and uses the proportion of the turbine, boilers, etc., no one else can use them at the same time, hence we must get from this particular customer each year the depreciation and the interest or dividends on their cost, since, of course, the electrical companies do not sell us dynamos nor the boiler companies boilers for nothing, and our stockholders do not give us money to pay for them unless they are assured of a reasonable return on their investment, which, as you know, has been only 5 per cent. for some years.

In addition to the interest and depreciation, and by the way taxes, which last year amounted to over 33 per cent. of the money we paid our stockholders, there are various other expenses which will be increased when we get ready to supply this new customer. We must keep the steam pipes hot from the boilers to the turbine even when no current is being turned out from the dynamo. We must keep two men by the turbine all the time to watch it and keep it oiled. We must keep a water tender at the boilers to see that the water does not get low in the boilers and cause trouble. We must keep men by the switchboard all the time to adjust the pressure that the lamps may neither be dim nor burn out, and there are various other expenses that will be required to get ready and keep ready to supply this customer even if no current be passing out over the lines. I will not describe all these expenses, because this paper is not on the subject of costs, but on the methods of making prices. I may say, however, that we figure that it will cost us, including the interest and depreciation on the plant required and the other expenses, something like $24,000 per annum merely to keep ready to supply this customer, and unless we get this sum for the keeping ready of this machinery we are out of pocket.

Now let us see what the cost is per kilowatt hour. First, let us take

a case so extreme as to be absurd but nevertheless instructive, and suppose that this customer used just one kilowatt hour. We may neglect the amount of coal used for one kilowatt hour, and we find that the total cost of that kilowatt hour was $24,000. Let us, however, take an extreme but not an absurd case, and suppose that this customer had his own plant but wanted central connection from us in case of a breakdown, and during one week of the year he shuts down his own plant and uses 24,000 kilowatt hours from us. The cost of the coal to us will be, we hope, something like one-half cent per kilowatt hour on our new turbine plant, and the coal for these 24,000 kilowatt hours will therefore cost us something like $120. Adding this to the $24,000 per annum that we pay for keeping ready and dividing by the kilowatt hours actually used, we find the cost a little over $1 per kilowatt hour.

Now take an ordinary case, a case similar to many we have on our books of other customers, and suppose that this customer should use his light about one hour per day and should use about 116,000 kilowatt hours. The cost of these for coal and for the renewal of the incandescent lights when they get dim or the trimming of the arc lights would be about $2,400, making the total cost, including the $24,000 per annum for keeping ready, about $26,400, or about 17 cents per kilowatt hour.

Take still another case, and suppose this customer used his lights about ten hours a day, say 1,200,000 kilowatt hours in all. Adding the cost of the coal and lamp renewals to the cost for keeping ready and dividing by the number of kilowatt hours, we find the rate to be about 3.2 cents per kilowatt hour; and of course if the customer should use his lights twenty-four hours per day the cost per kilowatt hour would be lower still. The above analysis has been for a customer with sufficient lamps to require one-tenth of one of our turbines. It is, however, perfectly obvious if we consider a customer who only requires one ten-thousandth of one of the turbines, say a customer with ten or twelve lamps, that the cost to him will be in the same proportion and the same per kilowatt hour as in the case of a large customer.

In addition, however, to all the expenses I have outlined that are actually increased every time a customer comes on our line there are a great many other expenses; for instance, when we lay a main in a street we have at first only one or two customers on the street, and these perhaps use only 1 per cent. of the whole capacity of the main. It would be bad engineering to put in a main so small that whenever a customer

came on it had to be dug up and replaced by a larger one; and yet the excess cost of the large main put in looking towards the future growth can hardly be charged to the particular customer who uses it first, but must be spread over the whole business, or rather charged to those customers who on the whole get the benefit.

Another expense of this nature is the fact that many of our engines are of older type than the modern turbine and involve considerably higher coal and labor cost. In our work we aim at keeping the total expense at a minimum. If we should throw away these old engines and put in turbines we could reduce our coal expense, but would increase our depreciation charge by an even greater amount; hence we run the old engines until we can afford to scrap them. But it would not be fair to charge the extra coal cost due to running these engines only to the old customers, for whom these engines were put in, and to give the whole advantage of the turbine to the new customers of this year; hence this extra cost forms an item which must be distributed over the whole business and cannot be ascribed to any particular customer. When the city of Boston abandons a street and makes us abandon our conduits without compensation, that again is an expense that cannot be ascribed to any particular customer. Besides these three sample cases there are many similar expenses; and without going into all of them in detail I may say that about half of the money that we collect from our customer goes towards paying expenses that cannot be said to be incurred for the benefit of any particular customer to whom they can be directly charged, but are incurred for the general good of all our customers, and are incurred most of all for the benefit of the small customers reached by our great network who could have the benefit of our supply, or rather of any supply of electricity, in no other way. In other words, half our expenses are for items that are for the general good of the city or of all our customers and that cannot be charged to any particular customer. Hence if a customer actually increases our expenses by say $10 we should, provided of course that he benefits by all our expenses, charge him a total of $20 as his fair share of all our expenses; and if he increases our expenses directly, by say $1,000, we should charge him a total of $2,000. If he increases our expenses by 17 cents for each kilowatt hour that he uses then we ought to charge him 34 cents per kilowatt hour in order that he may pay his fair share of our total expenses, and if he increases our expenses by 4 cents for each kilowatt hour that he uses then we ought to charge him 8 cents.

The difference between our increase of expense when such a customer comes on is of course not our profit, but is merely the proportion of our other expenses that such a customer should bear.

Unfortunately our prices were established before we knew just what the product was going to cost us, and we established a maximum price of 18 cents per kilowatt hour, much like the old woman who had a cow and a hen and tried to sell them for an average price of $15 each. She sold the cow all right, and we sold a great many kilowatt hours at 18 cents for which we ought to have had a much higher price. We also, because the art was new, sold some kilowatt hours at 18 cents for which we ought to have charged only 8 cents or so, and the profit on these made up for the loss on the other.

The case, however, was not and is not quite as bad as I have made out for the following reason. It is the customer who uses his lights and our machinery only a short time that costs the high amount per kilowatt hour; and when we have many such customers we find that, though nearly all of them use their lights at our peak, between four and five P.M. in the winter, there are some of them who use the lights at other times than this and do not use them at the time of the peak. Hence for short-hour customers we find we can, to a small extent, use the same machinery twice and get extra income, so that, allowing for this fact as worked out from our records, we find that a price of 20 to 25 cents would be a fair price for these short-hour customers. Nevertheless we have to keep our price down to 18, for if we should try to raise it we should have a row beside which Mr. Hearst's attempt at 80 cent gas would look like an editorial in the Boston *Transcript*. We can sell at 18 because this gives us a margin over the bare increase in expenses; but the customers who pay us 18 cents do not pay their fair share of our whole expenses and are among the least profitable of our customers.

If, however, a customer uses his lamps about one and one-fourth hours per day and pays us at the 18 cent rate, he pays us the cost of keeping ready to supply him; and after we are paid for the cost of keeping ready the cost to us of additional current is only the cost of the coal and lamp renewal and also an amount that we must allow to take account of the fact that while we can often sell the use of the same machinery twice to short-hour customers, yet long-hour customers are sure to use our machinery at the same time and must therefore be charged the full amount for the use of the machinery. To a customer who has used our machinery for a little over an hour a day at the

18 cent rate we therefore sell any additional current he may use at a lower rate.

If we made out our bills once a year the determination of the exact figures of hours and rates would be fairly simple; but as a matter of fact we render bills monthly, partly because we have some customers that we cannot trust for more than a month, but chiefly for the reason that our customers prefer monthly settlements. Now the fact that a customer in some months uses enough current at the 18 cent rate to pay us the cost of keeping ready in that month will not prevent his being a loss to us in some other month when he does not use enough current to pay even the cost of keeping ready. The fact that residences in the Back Bay use a good deal of current in the winter months does not prevent our having to pay interest and depreciation on the Back Bay investment in the summer months when the houses are closed. In order to allow for this we do not give the lower rate until the customer has used his lights and our machinery a little longer than enough to pay us the cost of keeping ready that month, and we make the low rate higher than would otherwise be necessary.

The exact figures we have adopted are that up to a use of from thirty to sixty hours per month, according to season, and totalling 520 hours per year, or about one and one-half hours per day, the rate is 18 cents and for any additional current only 12 cents.

The amount of our machinery that the customer uses is determined each month by an instrument called a demand indicator, or we often call it a discount indicator, because it indicates the point at which the discount from the 18 to the 12 cent rate begins.

Personally I do not think this monthly determination is the correct method, but that we ought to determine the amount of our machinery that the customer uses each year, since our business is a yearly one and the fact that our machinery is not used in summer does not save us any appreciable amount in our cost of keeping ready. I think it very probable that in the future we shall change this and take the reading of the discount indicator only once a year. This change will involve a reduction in the rate; otherwise taking the reading of the discount indicator yearly might result in increasing the bills.

The reason we make the time during which the 18 cent rate is charged 520 hours and the secondary rate 12 cents is in order to get a little profit in some months to make up for the months in which a customer fails to pay us even the cost of keeping ready to supply him.

If, however, a customer is a steady customer and every month uses enough current at the 18 cent rate to pay us this cost, then we are getting more out of him than we need and we say to such customer, "If you will *guarantee* to use your lights and our machinery for 400 hours and pay us at the rate of 20 cents (a less total than 18 cents for 520 hours), then we will give you the rest of your current at 8 cents." It would be simpler, of course, if the primary rates could have been uniform, *i. e.*, either 18 cents or both 20 cents. When we adopted this contract we had hopes that some day we might make the standard rate 20 cents, reducing the low rates still lower to balance it, but this is still a problem of the future.

In these contracts we take the yearly determination of the amount of machinery the customer has required us to keep ready for him, but we allow once a month that the customer can use an excess without charge, *i. e.*, once a month we permit the indicator to be cut out. The reason for this is that we can count that so few of these unusual demands will come at the time of our peak that we can afford to give our customers this privilege.

Our retail prices are therefore divided into two classes: non-contract, where a customer guarantees nothing and is usually a loss to us in some months, and contract rate, where a customer guarantees to use enough current at the high rate to insure us against loss and therefore gets the remainder of his current at a very low rate.

In addition to our retail rates we have wholesale discounts, and before describing how we make them I will explain why we make them. There is, of course, a difference in cost between supplying a large and a small customer, and the difference in cost as nearly as we can calculate is the same as the discounts we allow. The reason for this is that many of the special expenses that I spoke of before cannot be ascribed to any particular customer, yet we do know that they are not part of the cost of supplying certain classes.

The cost to us of supplying current in large quantities is considerably less than our average costs, since to supply all our customers we have to maintain a great network of mains; and incidental to this there are many expenses that are needed when we have many small customers, but are not needed when we supply the same quantity of current wholesale.

Since certain items of our expense are needed for small customers solely, on figuring the cost of supplying a large customer we do not

and should not include these expenses. For instance, when the city makes a change in a street and writes us to move our conduits at a large expense, the small customer says to us, "I must have electricity from you and am willing to pay my share," but the large customer says to us, "I can make electricity myself rather than pay the cost of moving the conduit."

It is clear, therefore, that moving this conduit is a part of our cost of supplying small customers and is not a part of our cost of supplying the large customer. The large customer may use the conduit; yet so long as the use of the conduit for the large customer does not add anything to the costs, it is clear that we cannot and ought not to try and make the large customers pay an expense not for his benefit, an expense that is incurred solely for the benefit of the small customers. Of course we should make our large customers pay every single expense that is incurred for their benefit; and if the conduit is in any degree for the benefit of the large customer, then to that extent and no more the large customer should pay.

Our wholesale discounts, therefore, are arranged to give our customers a rate in proportion to the cost to us to supply them. It is true that for large customers this is less than our average rate and average cost; but it should be kept clearly in mind that the small customer loses nothing in any way by the fact that the wholesale rate and wholesale cost to large customers is less than the retail rate and retail cost, and that the use of certain of our facilities by large customers at less than the average price does not add anything to the expense of supplying small customers.

The big department stores get no special advantage in competing with the small store by reason of our low wholesale cost for current, since the large stores already have the advantage of being able to put in a plant.

For the amount of current that would be used by a large customer who gets our wholesale discounts the cost of making so large an amount of current for himself in an isolated plant would be only 10 or 15 per cent. greater than our price to him. At first sight, therefore, it might seem that this 10 or 15 per cent. represents an advantage that the wholesale customer gets, as compared with his small competitor, over what he would get if we refused to supply him.

However, the wholesale customer gets his current we will say 15 per cent. cheaper than if we refused to supply him. If the retail customer

had to make his small amount of current for himself it would cost him, not 15 per cent., but 100 per cent. more than our price, so that the retail customer gets 100 per cent. and the wholesale customer only 15 per cent. advantage from the fact that the Edison Company exists.

Even take the worst case and suppose that we refused to supply the wholesale customer and did supply the retail customer. Even in this case the loss of the wholesale business would not decrease our expenses in proportion to the decrease in income, because the income is expected to be in excess of the expenses; so that if we lost the wholesale business, even at the present low rate, the cost of the retail business would be increased by the amount of the loss on the wholesale business, which would be much more than 15 per cent., and the small store would be more handicapped in competing with the large store than it is now.

I trust, therefore, that it is clear that our making all our prices, including our wholesale discounts, proportionate to cost is to the advantage of small customers as well as to the advantage of large customers.

The way we give the wholesale discounts to large customers is to give a discount of 40 per cent. on the excess of the monthly bill above $150, and 50 per cent. on the excess above $550. In this way we charge to the large customers some share of all these special expenses that are incurred for the benefit of our customers generally and small customers in particular, since on the first $150 of their bill they pay exactly the same rate per unit as the small customers. On the balance of the bill they get a discount to take account of the fact that a large proportion of our expenses is not incurred for them.

The reason for making the discounts on the excess of the bill rather than on the whole bill is to prevent the customer from saving money by wasting our current. If the discount is made say 20 per cent. on the whole bill whenever the bill gets to $200, then a bill of $199 gets no discount, while the use of a little more current gives a bill of $200, which is $180 net. On the plan of giving discount on the excess only we give 40 per cent. on the excess over $150, so that this feature of the customer's saving money by wasting current never enters.

It is important to note that the difference between our two methods of discounts is only in kind; they are both based on cost.

Our long-hour discounts are given because of the difference in cost. A long-hour customer costs us less per kilowatt hour than a short-hour customer; and we charge him less because, while he may use the same amount of machinery, which represents the larger element of cost, he

uses a larger amount of current, which represents the small element of cost, thus reducing the average cost per kilowatt hour used.

The wholesale discounts also depend on cost. A large customer costs us much less per kilowatt hour, or per kilowatt, than the equivalent number of smaller customers, and we charge them all in proportion to cost.

I will next speak of our minimum charge of $1 per month, which is a very interesting application of the same principle as that on which our wholesale discounts are based. For very small customers the cost of installing the service and meter and maintaining and reading the meter and making out and posting the bills and keeping the accounts comes to a very considerable sum in proportion to the cost of current alone, and amounts to about $8 per customer per year. Hence if a customer uses no current at all and we keep no machinery ready for him, nevertheless it costs us $8 to keep his meter there, and he ought to pay us $8 meter rent besides what he ought to pay us for his current. If we tried to charge this $8 in addition to the charge for current it would make the cost so high that these small customers would use no current at all. In these cases, therefore, as in the case of the big wholesale customers, we do not even attempt to collect from them the proportion of all our expenses, but only those expenses that are incurred for their benefit, and sometimes not even those. We cannot do this exactly, but the $1 per month minimum is the nearest we can come to it. If a customer uses no current at all he costs us $8, without reckoning the expense of the investment at his disposal, and we get $12. If a customer uses just $1 worth of current each month he costs us $8 for the meter, and his use of current adds $6 to our expenses that we would otherwise have to incur anyway, making a total of $14; and he pays us $12, or an actual loss of $2, not reckoning interest or depreciation on plant, etc.

If he uses $20 worth of current it adds to our expenses about $18 in all and we get $20, or only $2 towards our other special expenses, like moving conduits, etc., instead of $10, which would have been his fair share.

Besides our general rates for lighting, which I have described above, we have a special rate for power, because it can be supplied cheaper than light, a special rate for churches, which is a charity, and a rate for Central Station connection to isolated plants. We also have a price intermediate between our large wholesale discounts, which I have described, and the retail prices. I will not take up your time with these

various details of our large system because they are either founded on the principles of our regular rates or else they are excrescences on our system that we are going to get rid of as soon as possible.

Before closing I wish to say two things more and hope they will be of value in guiding any discussion. First, this paper is a paper on the principles and methods of making prices, and not a paper on costs, and I have not tried to give exact costs.

Second, as to the complications of such a system of prices as I have outlined. I was responsible for the introduction into this country of the Wright demand system of charging, on which the Boston Edison system is based, and have therefore heard a great deal about complication; but these systems are not as complicated as the United States Postal System, if one should attempt to explain the reasons why first-class rates should be exactly thirty-two times as much as second-class, etc.

They are not as complicated as the Boston water rates.

They are not as complicated as telephone rates.

They are not as complicated as railroad rates and classification.

They are not as complicated as a contractor's rates for excavating or piling or doing any work, unless he is allowed to make a guess and lump his estimates. I do not mean that one bid of a contractor may not be simple for excavating or other work, but you have no assurance that his next bid for the same work may not be higher or lower, or that his bid for similar work will be in the same proportion.

The only kinds of prices that are as simple as Boston prices for electricity are such as the price of Governor Douglas's $3 shoes, which are sold in a single quality and at retail only.

Before any one calls Boston Edison prices for electricity complicated I will ask him to name an article that is sold both wholesale and retail in qualities whose costs vary by several hundred per cent., an article that the customer may take delivery of at any time and in any amounts that he wishes, an article whose price is made so that the price will stand for several years without change, and whose price is not far more complicated than Boston Edison prices for electricity.

It would be possible, of course, to make our prices more simple, and in some directions we hope to simplify them later, but if we made our prices too simple they would be unfair, just as a hotel's prices would be unfair if it charged the same price for a boiled egg and a Porterhouse steak. A simple article like copper can have a simple price, but a complicated service like a railroad or a hotel or an electric service must have a complicated price in order that the price may be fair.

TENSION TESTS OF STEEL ANGLES WITH VARIOUS TYPES OF END-CONNECTION[1]

BY FRANK P. McKIBBEN

THE tension tests which form the subject of this paper were made in the testing laboratory of the Massachusetts Institute of Technology

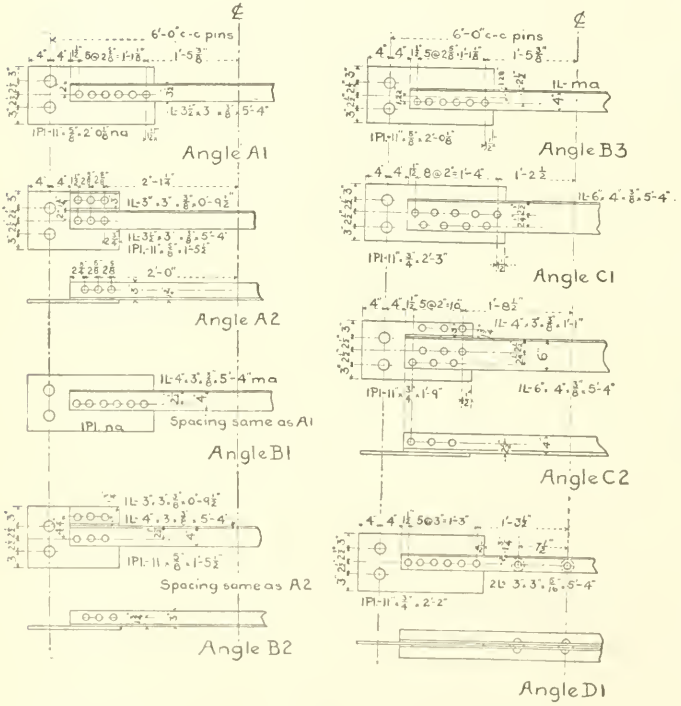

FIG. 1.—TENSION TESTS OF STEEL ANGLES

(Nine Types of End-Connection Tested)

NOTE.—All angles had both ends alike. All angles 5 ft. 4 ins. in length. Rivets, $\frac{7}{8}$-in. Holes punched, $\frac{15}{16}$-in. Pin holes, 2-in. diameter drilled.

upon twenty-seven specimens of rolled steel angles, such as are used for tension members in riveted structural work. They were made with a view of studying the following points:

1. The ultimate strength of the angles in tension.

[1] A paper read before the American Society for Testing Materials at Atlantic City, N. J., June 23, 1906. Reprinted from Engineering News, July 5, 1906, 56, No. 1.

2. The value of a lug in transmitting stress from the outstanding leg of the main angle into the hitch plate.

3. The relative strength of angles where the gauge line for rivets and where the centre of gravity line, respectively, pass through the centre of the pull.

4. The relative strength of single angles and angles riveted together to form pairs.

There are three specimens of each of nine different types, making in all twenty-seven specimens. These are shown in detail in Figure 1. Each of the main angles, 5 feet 4 inches in length, is riveted at each end to a hitch plate.

Types A_1, B_1, and C_1 consist each of one angle, $3\frac{1}{2} \times 3 \times \frac{3}{8}$ inches, $4 \times 3 \times \frac{3}{8}$ inches, and $6 \times 4 \times \frac{3}{8}$ inches, respectively, riveted to the hitch plates by one leg only.

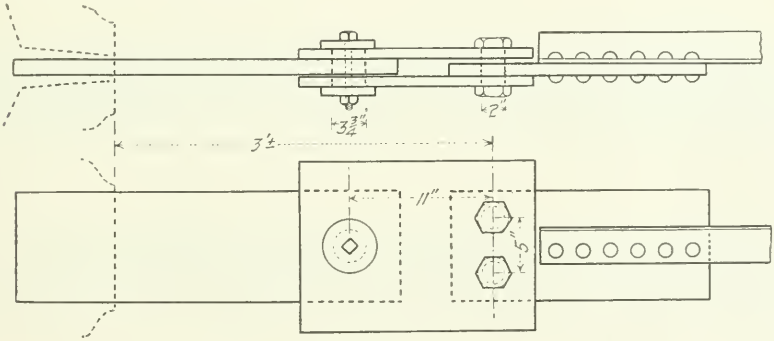

Fig. 2.—Tension Rigging for Tests of Steel Angles

Types A_2, B_2, and C_2 consist each of one angle of the same size as A_1, B_1, and C_1, respectively, and have both legs connected to the hitch plates, the outstanding leg being connected by means of a lug angle.

Each specimen of types D_1 and D_2 is made up of two $3 \times 3 \times \frac{5}{16}$ inch angles, one on either side of the hitch plate. D_1 is not, and D_2 is, provided with lugs for each of the outstanding legs of the main angles.

In each of the types just mentioned the gauge line for rivets in the main angle is run through the centre line of pull. In the case of angles with unequal legs the long leg is placed in contact with the hitch plates.

Type B_3 consists of one $4 \times 3 \times \frac{3}{8}$ inch angle connected to the hitch plates by one leg only. It differs from type B_1 in that the line of pull coincides with a projection of the centre of gravity line instead of with the gauge line for rivets.

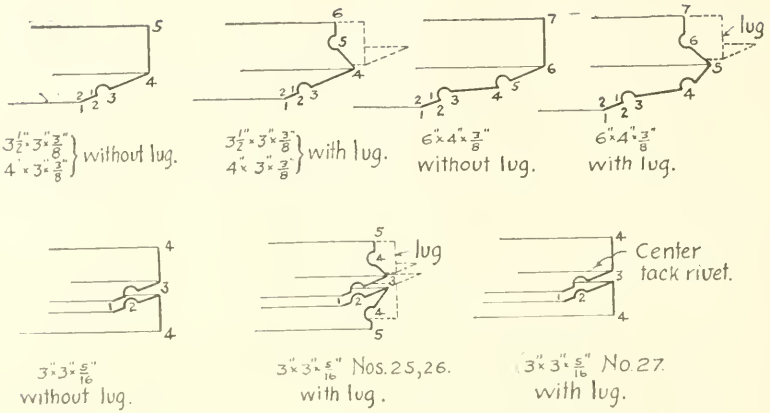

FIG. 3.—SKETCHES OF FRACTURES OF STEEL ANGLES WITH VARIOUS TYPES OF END-CONNECTION

(Small figures at fracture indicate origin and progress of rupture)

The end-connections were designed to insure failure in the main angles, and the specimens were made as long as could be tested conveniently. The hitch plate at each end of each specimen was provided with two 2-inch holes, by means of which it was pinned between two holding plates, fastened in turn by a single pin to a third plate gripped by the testing machine. A diagram of this holding device is shown in Figure 2.

All of the pieces of angles of a given size were cut from one long angle, and from each of these long pieces there were made also two small tensile test specimens. Table I gives the average results of the tensile tests on the small specimens, which were approximately 18 × $1\frac{1}{2} \times \frac{3}{8}$ or $\frac{5}{16}$ inches in size.

TABLE I—TENSILE STRENGTH OF SMALL TEST SPECIMENS CUT FROM STEEL ANGLES

Size of angle from which specimen was cut	$3\frac{1}{2} \times 3 \times \frac{3}{8}$ inches	$4 \times 3 \times \frac{3}{8}$ inches	$6 \times 4 \times \frac{3}{8}$ inches	$3 \times 3 \times \frac{5}{16}$ inches
Yield point, pounds per square inch	33,160.0	31,690.0	32,600.0	34,800.0
Ultimate strength, pounds per square inch	59,300.0	54,000.0	51,600.0	61,000.0
Elongation, per cent. in 8 inches	28.0	28.6	31.1	29.5
Reduction of area, per cent.	48.9	54.6	56.5	52.6
Appearance of fracture	Silky	Silky	Silky	Silky

Figure 3 shows diagrammatically the outlines of the various fractures, all of which occurred in the main angles. There was no failure of rivets. The numbers on the sketches show the sequence of the

fractures. With the exception of one of the specimens, made of two $3 \times 3 \times \frac{5}{16}$ inch angles, failure took place at one of the inner rivets which connects the angle to the hitch plate — that is, the connecting rivet which lies nearest the centre of the specimen. In the case of the exception noted rupture occurred at the centre of the specimen, where there is a single rivet connecting the two angles together. In all cases, just before failure the metal between the inner rivet and the outer edge of the leg connected by that rivet to the hitch plate drew down considerably at both ends of the specimen. Failure then occurred

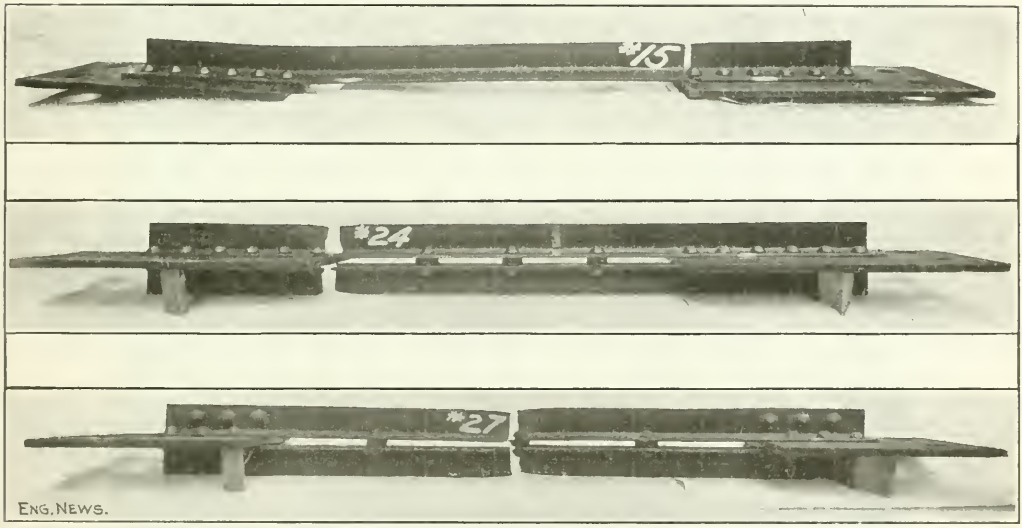

FIG. 4. — VIEWS OF THREE OF THE TEST SPECIMENS AFTER FRACTURE
(No. 27 was the only specimen which did not break at the end-connection)

at this point, continuing slowly across the horizontal leg and then up the vertical leg. With the one exception cited, failure occurred, in all specimens having lugs, on a zigzag section passing through rivets in the horizontal and in the vertical legs. In order to secure the greatest strength from an angle in tension this zigzag section should be equal to or greater than the net right section. In none of the specimens tested is this the case. Consequently the total ultimate strength of some of the specimens with lugs is less than that of similar specimens without the lugs. However, the strength per square inch of net area is greater where the lugs are provided, showing that with the proper spacing of rivets to utilize the maximum net area the lug is an advantage.

Table II shows in detail the results of the tests. Table III shows the per cent. increase in the strength per square inch of net area due to the lugs.

TABLE II — Summary of Tension Tests on Steel Angles

Type.	No. of specimens.	Nominal size.	Cross Section. Area in Square Inches.			Breaking Load.		Strength of material developed.[1]	Remarks.
			Nominal.	Actual gross.	Net.	Total.	Per square inch of net area.		
						Lbs.	Lbs.	%	
A_1	1	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.29	1.95	89,500	45,900	77.4	Without lugs
A_1	2	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.32	1.98	96,100	48,500	81.8	
A_1	3	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.35	2.00	95,200	47,600	80.2	
A_1	Mean	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.32	1.98	93,600	47,400	79.8	
A_2	4	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.28	1.78	84,600	47,500	80.1	With lugs
A_2	5	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.28	1.78	88,600	49,800	84.0	
A_2	6	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.27	1.77	91,200	51,500	86.8	
A_2	Mean	$3\frac{1}{2} \times 3 \times \frac{5}{16}$	2.30	2.28	1.78	88,100	49,600	83.6	
B_1	7	$4 \times 3 \times \frac{5}{16}$	2.49	2.44	2.10	85,000	40,500	75.0	Without lugs
B_1	8	$4 \times 3 \times \frac{5}{16}$	2.49	2.42	2.09	84,000	40,100	74.3	
B_1	9	$4 \times 3 \times \frac{5}{16}$	2.49	2.50	2.15	85,600	39,800	73.7	
B_1	Mean	$4 \times 3 \times \frac{5}{16}$	2.49	2.45	2.11	84,900	40,100	74.3	
B_2	10	$4 \times 3 \times \frac{5}{16}$	2.49	2.42	1.92	83,500	43,500	80.5	With lugs
B_2	11	$4 \times 3 \times \frac{5}{16}$	2.49	2.43	1.92	85,100	44,300	82.0	
B_2	12	$4 \times 3 \times \frac{5}{16}$	2.49	2.45	1.95	84,100	43,100	79.9	
B_2	Mean	$4 \times 3 \times \frac{5}{16}$	2.49	2.43	1.93	84,200	43,600	80.8	
B_3	13	$4 \times 3 \times \frac{5}{16}$	2.49	2.41	2.07	88,600	42,800	79.3	Without lugs
B_3	14	$4 \times 3 \times \frac{5}{16}$	2.49	2.42	2.09	90,400	43,200	80.0	Centre of gravity line through pull
B_3	15	$4 \times 3 \times \frac{5}{16}$	2.49	2.41	2.07	91,000	44,000	81.4	
B_3	Mean	$4 \times 3 \times \frac{5}{16}$	2.49	2.41	2.08	90,000	43,300	80.2	
C_1	16	$6 \times 4 \times \frac{5}{16}$	3.61	3.53	3.11	131,000	42,100	81.6	Without lugs
C_1	17	$6 \times 4 \times \frac{5}{16}$	3.61	3.54	3.12	125,700	40,300	78.1	
C_1	18	$6 \times 4 \times \frac{5}{16}$	3.61	3.50	3.07	128,200	41,800	81.1	
C_1	Mean	$6 \times 4 \times \frac{5}{16}$	3.61	3.52	3.10	128,300	41,400	80.3	
C_2	19	$6 \times 4 \times \frac{5}{16}$	3.61	3.50	3.04	131,500	43,300	84.0	With lugs
C_2	20	$6 \times 4 \times \frac{5}{16}$	3.61	3.50	3.03	130,200	42,900	83.2	
C_2	21	$6 \times 4 \times \frac{5}{16}$	3.61	3.50	3.04	131,900	43,400	84.1	
C_2	Mean	$6 \times 4 \times \frac{5}{16}$	3.61	3.50	3.04	131,200	43,200	83.7	
D_1	22	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.44	2.88	134,100	46,600	76.4	Without lugs
D_1	23	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.43	2.87	136,500	47,700	78.3	
D_1	24	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.49	2.91	139,100	47,800	78.4	
D_1	Mean	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.45	2.89	136,600	47,400	77.7	
D_2	25	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.43	2.69	137,900	51,200	84.0	With lugs
D_2	26	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.43	2.69	140,400	52,200	85.6	
D_2	27	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.42	2.86	138,800	48,500	79.6	
D_2	Mean	Two $3 \times 3 \times \frac{5}{16}$	3.56	3.43	2.75	139,000	50,600	83.1	

[1] Figures of previous column compared with specimen tensile test results of Table I.

The results of the tests show that the ultimate strength per square inch of net section for angles having gauge lines for rivets passing through the centre of pull varies, for the single angles, from 39,800 to 51,500 pounds, which is approximately from 74 per cent. to 87 per cent. of the strength of the tensile test specimens; and for angles

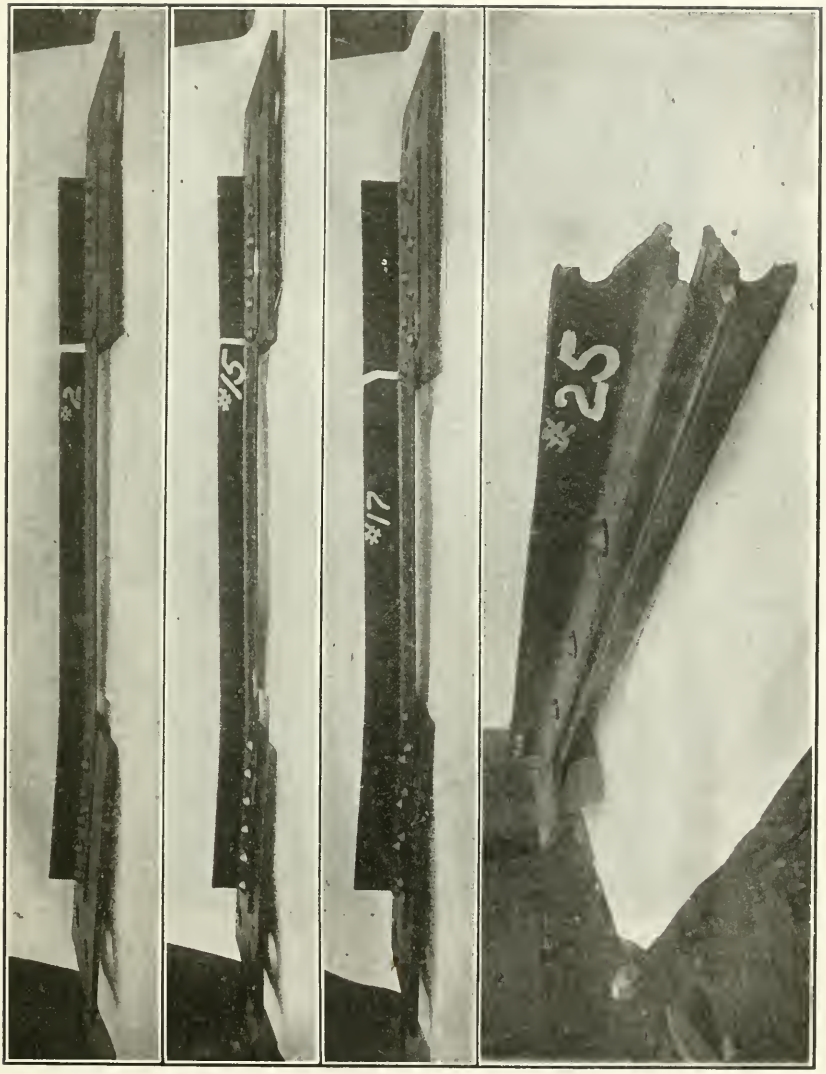

FIG. 5.— VIEWS OF FOUR OF THE TEST SPECIMENS AFTER FRACTURE
From *Engineering Record*

riveted together in pairs, from 46,600 to 52,200 pounds, which is approximately 77 per cent. to 86 per cent. of the strength of the material as developed by the tensile test specimens.

The efficiency of the lug is shown by the fact that for specimens provided with lugs there is an increase over specimens not so provided

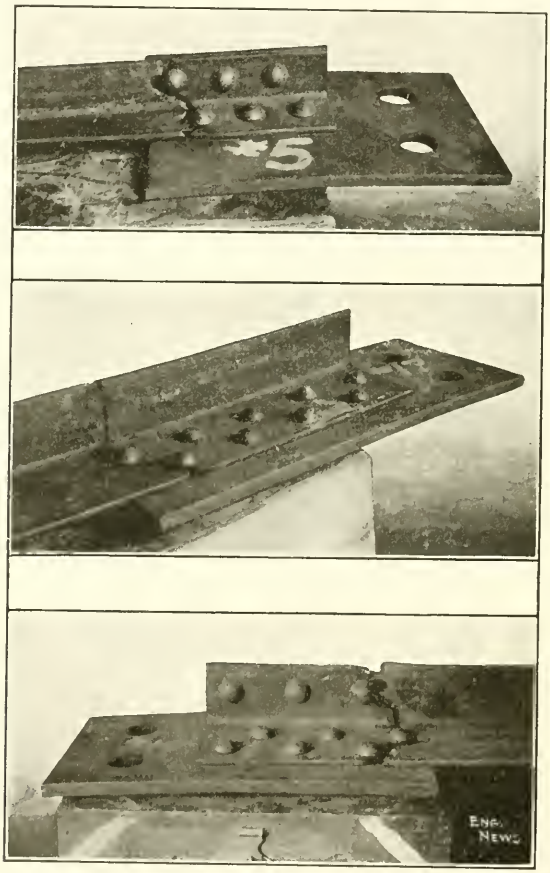

FIG. 6.—NEAR VIEWS OF THREE TYPICAL FRACTURES

of from 4.7 per cent. to 8.7 per cent. in ultimate strength per square inch.

A study of the results of the $4 \times 3 \times \frac{3}{8}$ inch angles without lugs shows that there is a gain of 8 per cent. in the strength per square inch for specimens having the line of pull coinciding with the projection of the centre of gravity line instead of the gauge line for

rivets. It further appears that for these angles the strength per square inch is practically the same for those specimens having the centre of gravity connections *without* lugs as it is for those having the gauge line connections *with* lugs.

TABLE III — SHOWING VALUE OF LUGS

Type.		Ultimate strength per square inch of net section.	Increase in strength per square inch of net area. %
A_1	Without lug	47,400	. .
A_2	With lug	49,600	4.7
B_1	Without lug	40,100	. .
B_2	With lug	43,600	8.7
C_1	Without lug	41,400	. .
C_2	With lug	43,200	4.4
D_1	Without lug	47,400	. .
D_2	With lug	50,600	6.8

Notwithstanding the fact that the net as well as the gross area of the two $3 \times 3 \times \frac{5}{16}$ inch angles is less than in any of the single $6 \times 4 \times \frac{3}{8}$ inch specimens, yet the ultimate load carried by the former is greater in every case.

This is, no doubt, largely due to the greater strength of the material in the double specimens on account of their smaller size and thickness.

In closing, the writer wishes to express his obligations to Messrs. Arthur L. Davis and S. P. Waldron, of the American Bridge Company, for the specimens tested, and to Messrs. A. F. Holmes, instructor, and C. T. Bartlett and H. P. Orcutt, students in the Massachusetts Institute of Technology, who carefully did the work in the laboratory.

BOOK REVIEWS

The Electrical Nature of Matter and Radio-activity[1]

In this work, the author has undertaken the task of presenting in an elementary and nonmathematical form the essential points in the large amount of material published in connection with radio-activity and the electron theory. The book is frankly popular in style, abounding in superlatives and italics, but shows the undoubted interest and enthusiasm of the author in the subject. It furnishes a good survey of the field, and will unquestionably be welcomed by those readers who, as the author says, "have a truly scientific interest in these most recent and important developments in physics and physical chemistry, but to whom a more technical and rigidly mathematical treatment might not appeal."

The greater portion of the book has already appeared in a series of articles in the *Electrical Review*. These articles have been revised, and the whole brought up to date by an additional chapter on recent researches. The first two chapters outline the work of J. J. Thomson on the electrical conductivity of gases, with special reference to the determination of the mass of the cathode particle. A brief presentation of the electron theory of matter follows in the two succeeding chapters. The remaining fourteen chapters are devoted to a discussion of the various radio-active substances, together with the radiations which they emit, the peculiar problems involved in their study, and the disintegration theory of Rutherford.

Such a subject as the electron theory is particularly hard to explain clearly in a nonmathematical form, so that the author is to be pardoned if at times the presentation of this portion seems somewhat unnecessarily detailed for a popular treatise. The book will in some degree meet the needs of all classes of readers except those already conversant with the subject. It should stimulate the general reader to interest in

[1] Harry C. Jones: Electrical Nature of Matter and Radio-activity. New York: Van Nostrand, 1906. $2.00.

these latest fruits of science; and to the scientist who has not investigated this field it will furnish a synopsis of the work hitherto done, together with references to the more important original articles.

C. M. Swan.

A Year-Book of Natural Science[1]

This small volume of 500 pages reviews the progress of science and technology in all their branches for the year 1905–06. When one considers the size of a volume usually required to do this for one branch of science alone, it is evident that the volume under review can accomplish its purpose only in a superficial manner. But from the fact that it is printed in German type it is apparent that this is intended to be only a popular review of the subjects of most interest to the general public.

In physics it takes up the questions of the day, such as the relations between light and electricity, radio-activity, and wireless telegraphy. In other branches of science, however, it may not reflect the most important thought so well; for example, in zoölogy, though the subjects mentioned are interesting, no hint is given of modern work in cytology and its relations to the wider problems which especially occupy the minds of biologists at the present time.

It is a book in which the general reader of scientific tastes would doubtless find much to interest him, and it might serve a teacher of modern languages as a source for sight reading in scientific German.

[1] Jahrbuch der Naturwissenschaften, 1905–06. Edited by Max Wildermann. Freiburg: Herder, 1906.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Society of Arts

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1906-1907

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BY-LAWS.

Objects of the Society.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind, which they are willing to contribute, to attend its meetings and become members. Persons having valuable inventions or discoveries which they wish to explain will find a suitable occasion in the Society meetings, subject to regulations hereafter provided; and while the Society will never indorse, by vote or diploma or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

Section I. — Administration.

The immediate management and control of the affairs of the Society of Arts shall be exercised by an Executive Committee, consisting of the President of the Institute and the Secretary of the Society (who shall be members *ex officiis*), and five other members, who shall be elected by the Society of Arts at each annual meeting, to continue in office until other persons have been chosen in their place.

Sect. II. — Duties of the Executive Committee.

The Executive Committee shall elect its chairman, prescribe his duties, and, with the concurrence of the Treasurer of the Institute, fix his compensation when the interests of the Society require that

he should be paid for his services; they may invite any person to preside at any ordinary meeting who is well versed in the subjects to be discussed; they shall appoint the days and times of meeting, when not fixed by the Society, and determine the subjects to be considered at the meetings and the mode of conducting the discussions; they may, with the concurrence of the President of the Institute, make such arrangements for reporting and publishing the proceedings of the Society as they may deem best suited to advance its interests; they may receive moneys in behalf of the Society in aid of its objects, by subscription, donation, or bequest; they shall make a report of their doings to the Society at its annual meeting and at such other times as a report may be called for by a majority of the members present at any meeting; they shall also make a report of their doings to the President of the Institute prior to the annual meeting, and at such other times as the Corporation may require it. Three members shall constitute a quorum for the transaction of business.

Sect. III. — Duties of the President and Secretary.

1. It shall be the duty of the President of the Institute to preside at the annual and the special meetings of the Society, and also at its ordinary meetings when the Executive Committee does not invite a special chairman to preside.

2. It shall be the duty of the Secretary of the Society to give notice of and attend all meetings of the Society and of the Executive Committee; to keep a record of the business and orders of each meeting, and read the same at the next meeting; to keep a list of the members of the Society, and notify them of their election and of their appointment on committees; and generally to devote his best efforts, under the direction of the Executive Committee, to forwarding the business and advancing the interests of the Society. He shall also record the names of the Executive Committee attending each meeting.

Sect. IV. — Funds of the Society.

All the fees and assessments of members, and all moneys received by subscription, donation, or otherwise, in aid of the Society, shall be paid into the treasury of the Corporation, to be held and used for the objects of the Society under the direction of the Executive Commit-

tee, and shall be subject to the order of its Chairman, countersigned by the President of the Corporation.

Sect. V. — Meetings of the Society.

1. The annual meeting of the Society shall be held at the Institute on the second Thursday in May. The ordinary meetings shall be held semi-monthly, or whenever deemed expedient by the Society or by the Executive Committee, excepting in the months of June, July, August, and September.

2. If from any cause the annual meeting shall not have been duly notified or held as above required, the same shall be notified and held at such time as the Executive Committee may direct.

3. A special meeting of the Society may at any time be called by the Secretary on a written request of ten members. Twelve members of the Society shall constitute a quorum for the transaction of business.

Sect. VI. — Members and Their Election.

1. Members of the Society of Arts shall be of three kinds — Associate, Corresponding, and Honorary Members.

2. Candidates for Associate Membership shall be recommended by not less than two members, whose signatures shall be affixed to a written or printed form to that effect. Each nomination shall be referred to the Executive Committee, and when reported favorably upon by them, and read by the Secretary, may be acted upon at the same meeting; the election shall be conducted by ballot, and affirmative votes to the number of three-fourths of the votes cast shall be necessary for an election.

3. Corresponding and Honorary Members may be elected in the same way, on nomination by the Executive Committee.

4. Associate Members shall pay an admission fee of three dollars before being entitled to the privileges of membership, and an annual assessment of three dollars on the first of October of each year, this sum to include subscription to the *Technology Quarterly and Proceedings of the Society of Arts.*

An Associate Member who shall have paid at any one time the sum of fifty dollars, or annual assessments for twenty years, shall become a member for life, and be thereafter exempted from annual assessments

A member neglecting to pay his annual assessment for six months after being notified that the same is due shall be regarded as having withdrawn his membership, unless otherwise decided by the Executive Committee, which shall be authorized, for cause shown, to remit the assessments for any one year; and which shall moreover be empowered to exempt particular members from assessments whenever their claims and the interests of the Society make it proper to do so.

Sect. VII. — Election of the Executive Committee and of the Secretary.

1. At an ordinary meeting of the Society, preceding the annual meeting, a nominating committee of *five* shall be chosen, whose duty it shall be to nominate candidates for the Executive Committee, to post a list of the names selected in the office of the Secretary, and to furnish printed copies thereof to the members at or before the time of election.

2. At a meeting at which an election is to take place the presiding officer shall appoint a committee to collect and count the votes and report the names and the number of votes for each candidate, whereupon he shall announce the same to the meeting.

3. A majority of the votes cast shall be necessary to an election.

4. In the first organization under these By-Laws, the Executive Committee may be elected at an ordinary or special meeting.

5. Vacancies in the committee occurring during the year may be filled by the Society at an ordinary meeting.

6. The Secretary shall be elected by the Society, on nomination by the Executive Committee, at each annual meeting of the Society, or, in case of a vacancy during the session, at such other time as the Executive Committee may appoint; and he shall be reëligible in the same way at the pleasure of the Society.

7. The compensation of the Secretary shall be fixed from year to year by the Executive Committee with the concurrence of the Treasurer of the Institute.

Sect. VIII. — Committees of Arts.

1. The Members of the Society of Arts may be enrolled in divisions, under the following heads, according to the taste or preference of

the individual; each division to constitute a committee upon the subjects to which it appertains:

(1) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2) On Organic Materials — their culture and preparation.

(3) On Tools and Implements.

(4) On Machinery and Motive Powers.

(5) On Textile Manufactures.

(6) On Manufactures of Wood, Leather, Paper, India Rubber, and Gutta Percha.

(7) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8) On Chemical Products and Processes.

(9) On Household Economy; including Warming, Illumination, Water-Supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10) On Engineering, Architecture, and Ship-building.

(11) On Commerce, Marine Navigation, and Inland Transportation.

(12) On Agriculture and Rural Affairs.

(13) On the Graphic and Fine Arts.

(14) On Ordnance, Firearms, and Military Equipments.

(15) On Physical Apparatus.

2. Any member may belong to more than one of the above-named Committees of Arts, but shall not at the same time be eligible as chairman in more than one.

3. It shall be competent for each Committee of Arts, of ten or more members entitled to vote, to organize; to elect annually in October, or whenever a vacancy shall occur, a chairman; to appoint its own meetings; and to frame its own By-Laws, provided the same do not conflict with the regulations of the Society of Arts.

Sect. IX. — Amendment and Repeal.

1. These By-Laws may be amended or repealed, or other provisions added, by a vote of three-fourths of the members present at any regular meeting of the Society; provided that such changes shall have been recommended and approved in accordance with the By-Laws of the Corporation (see extract from By-Laws of Corporation as

printed below) and presented in writing at a preceding meeting of the Society.

2. These By-Laws shall take effect immediately after their approval by the Corporation and adoption by the Society, and all previous By-Laws are hereby repealed.

As amended December 9, 1897.

Extract from the By-Laws of the Corporation.

Sect. VI. — There shall be a Committee on the Society of Arts consisting of five members, appointed at the annual meeting of the Corporation, to hold office for one year, who shall have the general charge and supervision of the organization and proceedings of the Society, subject to the approval of the Corporation. It shall be their duty, in connection with a committee chosen by the Society, to frame By-Laws for the government of the Society, which shall take effect when adopted by the Society and approved by the Corporation.

Revised February 1, 1894.

LIST OF MEMBERS

DECEMBER, 1906

Members are requested to inform the Secretary of any change of address

THE CORPORATION

Life Members

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* Carson, Howard A. . . . . 15 Beacon Street, Boston, Mass.
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Draper, Eben S. . . . . Hopedale, Mass.
** Endicott, William . . . . . 32 Beacon Street, Boston, Mass.
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Fish, Frederick P. . . . . 125 Milk Street, Boston, Mass.
* FitzGerald, Desmond . 408 Washington Street, Brookline, Mass.
* Freeman, John R. . . . 815 Banigan Building, Providence, R. I.
Higginson, Francis L. . . . . 274 Beacon Street, Boston, Mass.
Hubbard, Charles W. . . . . 133 Essex Street, Boston, Mass.
Jackson, Charles C. . . . . 19 Congress Street, Boston, Mass.
Lee, Elliot Cabot . . . . . Brookline, Mass.
Lincoln, William H. . . . 1151 Tremont Building, Boston, Mass.
Livermore, Thomas L. . . . 12 Ashburton Place, Boston, Mass.
Lovering, Charles L. . . 53 State Street, Room 843, Boston, Mass.
* Lowell, A. Lawrence . . 171 Marlborough Street, Boston, Mass.
* Lowell, Percival . . . . . 53 State Street, Boston, Mass.
Mills, Hiram F. . . . . 266 Andover Street, Lowell, Mass.
* Munroe, James P. . . . . 79 Summer Street, Boston, Mass.
Paine, Charles J. . . . . 613 Sears Building, Boston, Mass.
Peabody, Robert S. . . . . 22 The Fenway, Boston, Mass.
Pritchett, Henry S. . . Mass. Institute of Technology, Boston, Mass.
Putnam, William Lowell . . . . . 60 State Street, Boston, Mass.

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Sewall, J. B.	Brandon Hall, Brookline, Mass.
Stearns, James P.	National Shawmut Bank, Boston, Mass.
* Stockton, Howard	50 State Street, Boston, Mass.
* Stone, Charles A.	84 State Street, Boston, Mass.
Thayer, Nathaniel	50 State Street, Room 82, Boston, Mass.
* Thomson, Elihu	42 Centre Street, West Lynn, Mass.
* Tolman, James P.	88 Broad Street, Boston, Mass.
Tuttle, Lucius	3 North Station, Boston, Mass.
Weld, Charles G.	70 Kilby Street, Boston, Mass.
Wheeler, Alexander S.	72 Marlborough Street, Boston, Mass.
Whitney, David R.	85 Devonshire Street, Boston, Mass.
* Wigglesworth, George	53 State Street, Boston, Mass.
* Williams, Francis H.	505 Beacon Street, Boston, Mass.

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Soule, Richard H.	1571 Beacon Street, Brookline, Mass.
Stevens, Eben S.	Quinebaug, Conn.

Term expires March, 1910

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Term expires March, 1911

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* Main, Charles T.	1110 Exchange Building, Boston, Mass.
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Burton, A. E. . . . Mass. Institute of Technology, Boston, Mass.

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Crosby, William W. . . . . 8 Court Street, Woburn, Mass.
Cross, C. R. . . . . Mass. Institute of Technology, Boston, Mass.
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Cutter, Louis F. . . . . 33 Chestnut Street, Salem, Mass.

Dabney, Herbert . . . . . 45 Broad Street, Boston, Mass.
Dana, Gorham . . . . . 258 Walnut Street, Brookline, Mass.
Dates, Henry B. . Case School of Applied Science, Cleveland, Ohio
Day, Ernest W. . . . . 225 Mt. Auburn Street, Watertown, Mass.
Day, Nathan B. . . . . 280 Newbury Street, Boston, Mass.
De Berard, Wilford W. . . Board of Public Works, Columbus, Ohio
Densmore, Edward D. . . . 15 Exchange Street, Boston, Mass.
De Wolf, John O. . . . . 159 Devonshire Street, Boston, Mass.

Doolittle, Orrin S. . . . . 404 Warburton Avenue, Yonkers, N. Y.
Dow, Richard E. . . . . Melrose, Mass.
Draper, William L. . . . . Atlanta, Ga.
Dudley, P. H. . . . . 80 Pine Street, New York, N. Y.
Dunbar, W. O. . . . . 1218 13th Street, Altoona, Pa.
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THE MINERALOGICAL EXAMINATION OF SANDS

By CHARLES H. WARREN

The method of investigation which is to be described in this paper was developed by the writer for the purpose of examining mineralogically, in a rapid and systematic manner, a large number of samples of river and sea sands, or concentrates from such sands, submitted to him by Dr. David T. Day, in connection with the extensive economic study of sands and gravels which is being carried on under Dr. Day's direction by the United States Geological Survey.

In practice, besides purely qualitative results, the method made it possible, when minerals of economic interest were detected, to make a rough estimate of the relative amounts of these, in order to show whether or not the probable value of the sand was sufficient to warrant the making of an exact chemical determination of the one or more valuable elements present. While especial pains were taken to devise a method of procedure the main object of which should be the detection, with as great a degree of certainty as possible, of the significant quantities of minerals having an economic value, the detection of the associated minerals was not neglected, since a full knowledge of these is often of great importance when questions of treatment and extraction arise, to say nothing of the importance of such information from a purely mineralogical or geological point of view.

The economic minerals, whose presence or absence in a sand it is the aim of the following procedure to detect, may be listed as follows:

Magnetite, hematite, limonite.

Psilomelane and other manganese oxides.

Chromite.

Ilmenite, rutile (brookite, octahedrite).

Cassiterite.

Wolframite, hübnerite, scheelite.

Columbite, tantalite, other niobates, tantalites, and titanites.

Uraninite.

Monazite and other related rare-earth minerals.

Abrasive and gem minerals, such as corundum, garnet, diamond.

Gold and platinum metals.

It is, perhaps, almost unnecessary to say here that the detection of small values of gold and platinum metals can only be accomplished by regular assay methods.

A moment's thought regarding the time, labor, and expense involved in making any quantitative chemical estimations of such elements as chromium, titanium, tantalum, tungsten, or the rare-earths will make it evident how very important a reliable preliminary mineral examination is where these rare elements are to be looked for.

While the procedure contains little essentially new to those familiar with modern methods of mineralogical and petrographical investigation, it is believed that this particular application of these methods will be of interest and practical use to those who may have such examinations to make. It is also the writer's hope that it may serve to direct anew the attention of those interested in the mining, testing, or analysis of mineral products, whether sands or not, to the practical value of a careful mineralogical examination by competent parties before launching out into expensive analytical work. The writer could cite very many instances of much time and money wasted for the lack of such simple precautionary measures.

The main lines of attack followed in examining a sample may be briefly summarized as follows:

1. Sizing with screens.

2. Concentration of the heavier minerals with the pan or table, if the sample has not been previously concentrated.

3. Separation into several fractions with the aid of magnets.

4. Examination of these several portions:
   (*a*) with hand lens, noting color, crystalline habit, structure, etc.;
   (*b*) as to streak and hardness;
   (*c*) as to specific gravity of constituents;
   (*d*) as to microscopic characters of the mineral grains;
   (*e*) by means of blowpipe and other chemical tests.

Sizing. — After weighing the sample it is screened through a 24 to 30-mesh (to the inch) sieve. This size mesh yields an undersize well suited for the magnetic treatment, and an oversize which is as fine-grained as can advantageously be examined by the ordinary methods of Determinative Mineralogy. Where sands or gravels which have not been mechanically concentrated and evidently consist largely of quartz, clay, and other light, valueless constituents are to be examined, the sample should, after the removal of the oversize, be panned, jigged, or, better yet, run over a concentrating table, if the latter is available, in order to obtain a sample or samples of smaller size and with a greater concentration of minerals likely to be valuable. If the concentrating table is resorted to it is only necessary to examine the heads and middlings. Many times a rapid inspection of the middlings with a good lens or with the microscope will show that this portion, too, may be discarded. The methods of examination which follow, therefore, apply especially to concentrates from the original sand or gravel. In particular sands, where for any reason especially elaborate magnetic fractioning is desired, the sample is sized through a number of screens of different fineness — the size most suitable in a particular case being determined by experiment, in order to obtain portions in which there will be a fairly uniform size of grain. With the majority of sands the greater part will pass through into the undersize.

Examination of the Oversize. — Aided by the use of a good hand lens, a small magnet, a piece of Arkansas stone (streak stone), a knife, and an occasional blowpipe or simple wet test, one can, with a fairly good knowledge of minerals, determine in most cases, quickly and easily, the minerals present in the oversize and estimate roughly their amount. In the few cases where minerals are found which cannot thus be identified easily, a more elaborate examination must be made, preferably with the aid of Brush and Penfield's determinative tables and some descriptive text. While it is true that any of the minerals possessing chemical and physical properties capable of resisting the natural agents of weathering and disintegration may at times be met with in the oversize, it is also

true that in general only the more common minerals will be found. The mineral character of the oversize is naturally suggestive as to what may be found in the undersize. It is, however, unsafe to rely on such evidence, as the two nearly always differ more or less widely, and are not infrequently radically different.

Examination of the Undersize. Magnetic Treatment. — If the undersize from the sample is a large one, a 25-gram portion is weighed out, care being taken that it is a well-mixed, representative one. If the undersize is small it is taken entire. In either case the portion is next heated in a suitable dish until all hydroscopic moisture is driven off. This prevents the grains from adhering to one another or to the magnets. This sand is then spread out one grain thick on a glass plate, and several fractions are made, consisting of mineral grains of nearly the same magnetic susceptibility, with powerful electro-magnets. It is impossible to get a sharp magnetic fraction, that is, one in which all the grains of the same magnetic susceptibility are picked up at a given distance with a field of given magnetic strength, unless the grains are uniform as to size and shape. Hence when a preliminary examination detects the presence of minerals of interest or points to their probable presence in a sample, it is desirable to screen the sand, as suggested above, so as to get fractions of as uniform a size of grain as possible, and then to make a careful magnetic fractioning of each size, adjusting the strength of the magnet and jumping distance of the grains by experiment until the simplest mineral fractions are obtained. Such a treatment may often result in fractions consisting practically of a single mineral species. It should always be borne in mind in making magnetic fractions that their purity may often be affected seriously by included or adhering grains of a strongly magnetic mineral.

The first fraction is taken out with a large-sized, powerful single-pole electro-magnet fixed at a distance of about $1\frac{1}{2}$ inches above the grains. The strength of the magnet should be so adjusted that it will not pick up crystalline hematite or ilmenite grains except on actually touching them (the writer used grains of crystalline Elba hematite which had been passed through a 24-mesh sieve as a standard). The magnet should be cleaned frequently so as not to allow any considerable thickness of magnetic grains to diminish the jumping distance from the plate. This portion will be called M_1.

The grains remaining on the plate are next passed *slowly* under a powerful two-pole electro-magnet. The distance of the poles above

the grains may conveniently be about 5 to 6 mm., and the current strength regulated so that hematite and ilmenite grains, of size comparable with that of the sand, are easily picked up, but not common red garnet (almandite).

Here especial care should be taken to prevent the accumulation on the magnet of a layer of grains much over a millimeter thick. Except in cases where the amount of material picked up is relatively small, the separation is usually repeated, thus recovering silicates and other minerals carried up by the strong mechanical action of the jumping grains. This portion will be called M_2. Where for any reason considerable quantities of silicates are found in this fraction, they may often be separated readily by a suitable adjustment, determined by experiment, of the jumping distance or the current strength.

The remainder is again passed under the magnet, working at full strength and with the poles barely touching the grains. The portion picked up is again subjected to the same treatment; the product which is still picked up is labeled M_3 and the nonmagnetic portion M_4. Here, again, the fraction may often be divided into smaller and simpler mineral fractions by using different jumping distances or current strengths. For example, in a certain sand examined by the writer the minerals present in M_3 were practically all removed at about 4 mm., a clean garnet fraction made at about 2.5 mm., leaving a residue consisting entirely of a deep amber monazite. The examination of the four magnetic fractions will be discussed in order below.

Magnets. — Any single-pole electro-magnet of fair size, say with a core about an inch in diameter, and of good strength may be used for the first separation. The stronger the magnet the better, since a longer jumping distance may be used with a stronger magnet. The longer the jumping distance the greater, in general, will be the chance for particles, picked up by the rush of magnetic grains, to drop back to the plate. A weak two-pole magnet can, of course, be used here; but the writer has found that with strongly magnetic material like magnetite the relatively straight field of the single-pole magnet gives a fraction cleaner from mechanically included nonmagnetic or feebly magnetic grains than the double-pole field.

For taking out fractions M_2 and M_3 a double-pole electro-magnet capable of giving a very intense, highly concentrated field is required. The distance between the poles must therefore be small and the poles themselves brought to a sharp, wedge-shaped termination.

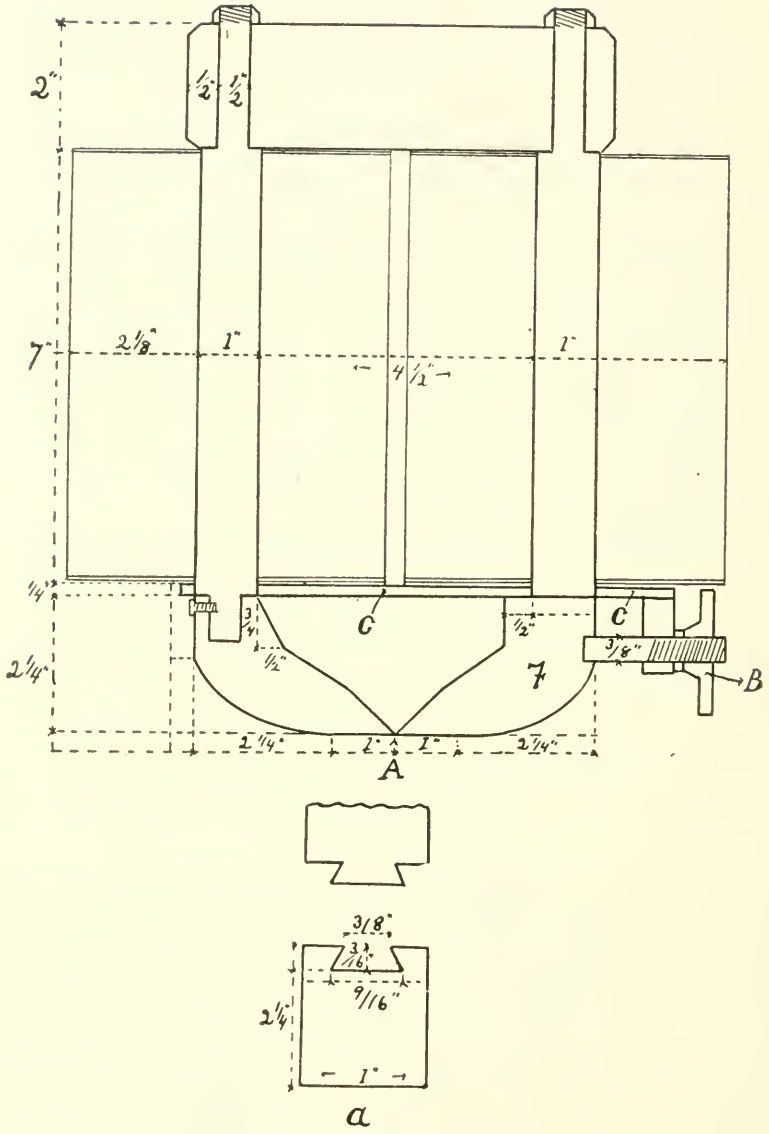


FIG. 1. — FRONT VERTICAL SECTION OF THE MAGNET

A, air space; *B*, brass wheel; *C*, brass bar; *F*, pole piece; *a*, cross section of *F*

For those who may wish to build a magnet for laboratory work, the accompanying diagram and the following brief description of a magnet designed by the writer for use in the mineralogical laboratory

of the Institute may be of value. Figure 1 shows a front vertical section of this magnet. The iron parts are very carefully fitted together so as to do away with any air spaces, and all were thoroughly annealed before finally being put together. The top crossbar is made to extend out over the core pieces on the front and back, as well as on the side (as shown in the plan), so as to ensure the passage of practically all the magnetic flux through the iron. For the same reason the pole pieces are made somewhat heavier than the cores. One of the pole pieces (*F*) is grooved so as to run nicely on a track cut on the end of the core piece. This is shown in side view in Figure 1*a*. Into this pole piece is fastened an iron rod, which is finely threaded for about an inch and made to run through a brass wheel (*B*). This wheel is attached by means of a brass bearing to a brass bar (*C*). The bar (*C*) also serves the purpose of holding the iron cores rigidly in place, and thus prevents a possible movement toward one another when the magnet is working at full strength. By means of the wheel the pole can be moved and the length of the air space (*A*) varied as desired. In practice a gap of about $\frac{3}{16}$ of an inch is generally used. The poles come to a sharp edge 1 inch long.

The winding is on two light brass spools having inside dimensions 7 inches long by $2\frac{1}{8}$ inches deep. These allow for, approximately, 4,000 feet each of No. 18, double cotton-covered, copper wire. As a matter of precaution the coils are separated from the spools by two layers of paper. The magnet is run directly on a 110-volt current for its full strength, which, of course, can be cut down by the introduction into the circuit of suitable resistance. By using poles which are terminated with truncated cones, whose sides have a slope of 40 or 60°, either a field of uniform or maximum intensity, respectively, can be obtained, and the magnet becomes useful for demonstrating the magnetic properties of crystals or of crystal sections.

Strongly Magnetic Portion. M_1. — The portion taken out by the first treatment consists, in general, largely or entirely of magnetite. In some sands, where ilmenite and hematite and limonite adhere to or are intergrown with the magnetite, very considerable portions of these minerals will be found in M_1; and in any case, if these minerals are abundant in the sand, a variable amount will always be swept up by the rush of magnetite particles. The ilmenite, etc., while not actually picked up if alone, are strongly affected by the magnetic flux, and are thus virtually rendered lighter, so that the "sweeping up" takes place

all the more easily. Small amounts of other unimportant minerals may adhere to the magnetite or be carried up mechanically, but in general the fraction represents roughly the amount of magnetite present in the sand. If present, meteoric or terrestrial iron and the nickel iron alloys, awaruite and josephenite, would be found in M_1. The writer has never observed these latter in the undersize, and unless present in considerable amounts they would be difficult to detect where the undersize was fine. Where the grain was coarser they could probably be recognized by their steel-like surface and their toughness under the hammer or pestle. If desired, the magnetite portion may be tested chemically for titanium as described beyond.

Magnetic Fraction. M_2. — The minerals most commonly met with in this portion are ilmenite, hematite, chromite, limonite; less commonly, hypersthene, garnet, hornblende, pyroxenes (often here because of abundant inclusions of magnetite), iron-rich epidotes; rarely, rutile altered on the surface to ilmenite, wolframite, columbite-tantalite, samarskite, or related minerals. It is true that many other minerals of little or no commercial value might be found here in small quantities, calling for an amount of labor to identify them, if indeed they could be identified at all, out of all proportion to the importance of the mere fact of their being present in this fraction.

A careful examination of the fraction with a powerful lens should be made first. The important characteristics which may be noted are tabulated below, together with the names of the corresponding minerals. It may be remarked here that even with a comparatively short experience in examining these sands the eye becomes very expert in detecting distinctions of color and lustre too fine to be described.

Name of Species	More Important Characteristics
Ilmenite.	Black, shiny, crystalline plates, often with hexagonal outline; edges frequently highly modified; bases commonly pitted. Also crystals of pseudo-octahedral habit, due to nearly equal development of the rhombohedral $(10\bar{1}1)$ faces and the base (0001). Flat plates with rounded (worn) edges. Commonly as iron-black, rounded, irregular grains.
Hematite (Turgite).	Occasionally as iron-black or gray, shiny, hexagonal, tabular, and pseudo-octahedral crystals, similar to ilmenite. Sometimes as black or reddish black octahedral crystals after magnetite (martite); also cubical and pyritohedral after pyrite. Thin plates and scales; gray by reflected,

Name of Species	More Important Characteristics
Hematite (Turgite).	opaque or dark red by transmitted light. Commonly in rounded, irregular grains, sometimes fibrous in structure, black or reddish in color. (The massive and fibrous forms are often turgite.)
Limonite (Goethite).	Limonite as black to brownish black cubes, octahedrons, pyritohedrons, pseudomorphic after pyrite. Commonly (also goethite) in prismatic, radiated, irregular, rounded grains; often fibrous.
Chromite.	Black (usually pitch black) octahedrons, more or less rounded, often nearly spherical grains, showing a shiny black conchoidal fracture.
Wolframite.	Black or brownish black rounded grains, showing, where broken, a good cleavage in one direction.
Samarskite, or related minerals.	Black or brownish black grains with a resinous or pitchy lustre. Show a pronounced conchoidal fracture.
Columbite-tantalite.	Black or bluish black grains; nothing particularly characteristic.
Garnet.	Dodecahedral and trapezohedral crystals more or less rounded, the smaller crystals being usually quite perfect. Color, various shades of red, also blackish and brown.
Hypersthene.	Greenish brown, square, elongated prisms, with the ends usually rounded. The prisms and ends are sometimes truncated by small faces. Less commonly as rounded grains.
Hornblende.	Black, lustrous, prismatic, angular grains, frequently exhibiting the two excellent prismatic cleavages of hornblende; also as dull, rounded grains.
Pyroxene (Augite).	Usually as brownish or greenish black, rounded grains, sometimes showing a square prismatic form.
Tourmaline.	Black, irregular, rounded grains, sometimes prismatic; striated longitudinally; vitreous lustre.
Serpentine.	Light to dark green; also yellowish, round, opaque, or semitransparent grains, with inclusions of iron ores.

There are no other minerals likely to occur in this fraction which could be recognized at sight by any characteristic appearance under the hand lens. The microscopic characteristics of the minerals occurring here which transmit light are the same as those described under M_3, and will be taken up there.

A further study of this portion may be made as follows: about one-half a gram of the well-mixed portion is reduced to a *very fine* powder.

Streak. — The color of the powder (streak) should be noted, as it may throw light on the composition of the sample. Some of the powder should be rubbed out very thin on paper, so as to get the color of the finest dust. This is important, as many powders appearing almost black will show a very noticeable and often characteristic color if rubbed on the paper.

In a general way:

a red streak points to ferric oxide, hematite, or turgite;

a dark reddish brown streak *may* indicate wolframite or columbite;

an ochre brown streak indicates limonite;

a pure brown streak indicates chromite;

a black streak indicates ilmenite;

a light-colored streak — red, brown, or gray — points to the presence of silicates.

Chromium. — About 0.2 mg. of the powder is introduced into a borax bead (3 mm. diameter) on a loop of platinum wire, and heated in a strong reducing flame before the blowpipe. A characteristic emerald-green bead (when cold) is obtained (best seen against a white background) if chromium is present in the fraction. Actual tests made by the writer on carefully prepared and weighed mixtures of the minerals coming in this magnetic fraction of the sands have shown that this test is not obscured by any of the elements present in the minerals. To the practiced eye the test is reliable if 1 per cent. of chromium is present in the fraction, and of course this represents a much smaller percentage in the sand. To any one not thoroughly familiar with the particular shade of green given by chromium, it is important to have two borax beads, one with a very small amount of some chromium salt and the other with about 0.2 mg. of ilmenite dissolved in it, for comparison.

Titanium and Tungsten. — From 0.2 to 0.3 gram of the powder is next mixed with five or six volumes of soda and fused thoroughly on a piece of charcoal before the blowpipe. (In rare instances a faint coating of oxide of tin may be obtained on the coal. The tin may come from varieties of columbite, wolframite, or even from cassiterite mechanically carried up, or where the latter is intimately intergrown with oxide of iron.) The fusion is cut from the coal, powdered in a

mortar, and boiled in a test tube thoroughly with four successive 10 c.c. portions of water, the liquid being decanted through a filter so as not to disturb the residue. The filtrates from the first two leachings are caught in a test tube, acidified, and boiled with hydrochloric acid. If tungsten is present to the extent of about one-half of 1 per cent. an opalescence will appear in the solution; and if a piece of tin is added and the solution boiled for three or four minutes a characteristic blue coloration appears, and eventually a small deep blue precipitate settles to the bottom of the tube. If tungsten is present in large quantity a thick, white cloud separates on acidifying, which readily changes on boiling into the yellow tungstic acid, and this becomes deep blue when reduced with tin.

The residue insoluble in water is now boiled thoroughly with hydrochloric acid, poured through a filter to remove charcoal and any undecomposed mineral, and boiled down with metallic tin. If titanium is present in amount exceeding about 3 per cent. a distinct violet color will be obtained. If no color is obtained, and it is important to know the titanium content, the amount may be estimated colorimetrically by the well-known hydrogen peroxide method. Some titanium is almost invariably present.

Tantalum. — Unless fragments of minerals carrying tantalum are found in the oversize, when there is no difficulty in identifying them, there is very little chance of their being recognized or their presence proved in the undersize unless very considerable amounts are present. The characteristic pitchy lustre of samarskite, euxenite, and other similar minerals may be recognized when the grains are fairly abundant if the erosion undergone by the grains has not destroyed their lustre.

So far as the writer is aware, there is no quick or simple test for small quantities of tantalum in the presence of titanium. The element niobium, which usually accompanies tantalum, can be detected with less difficulty; but if tantalum and niobium are present in an amount less than about 5 per cent. they cannot be detected with certainty without an elaborate qualitative test, such as is recommended by Professor A. A. Noyes.[1]

Where niobium is present in as large amounts as 10 per cent. and tungsten is absent, or removed by fusion with soda and leaching, a very

[1] Technology Quarterly, XVII, No. 3, September, 1904.

satisfactory test for niobium may be made as follows:[1] About 0.1 gram of mineral is fused with three or four volumes of borax, the fusion dissolved in hydrochloric acid and reduced with a piece of granulated tin. The violet of titanium appears first, but later takes on a bluish shade and becomes quite blue on longer boiling. With smaller amounts than 10 per cent. present, the writer has not been able to get satisfactory results.

Magnetic Fraction. M_3. — In this fraction we may find any of the minerals mentioned under M_2. Where care has been taken in making the magnetic separation, this fraction will usually contain relatively little hematite, ilmenite, or iron-rich chromite. Slight variation in the chemical composition, in the size of the grains, in the way they lie (on edge or face) doubtless accounts for the distribution of essentially the same mineral species through both of these magnetic fractions. The proportion of the silicates in M_3 to the metallic minerals is, however, in general much greater than in M_2. The less strongly magnetic varieties of the metallic oxide minerals and of columbite-tantalite and wolframite are also more abundant here. Uraninite may be found here if the magnetic pole touches the grains. The deeper colored varieties of monazite may also be found in M_3, sometimes quite abundantly. Grains of quartz and other nonmagnetic minerals which have become covered or filled with iron rust are also very commonly picked up at this point.

As suggested earlier, both M_2 and M_3 may in special cases be subjected to a much more elaborate magnetic fractioning, in which case the microscopic and other tests are often much simplified.

The remarks regarding the habit of the metallic mineral grains and the streak given under M_2 apply to this fraction as well. The same chemical and blowpipe tests are also applicable, with an additional test for monazite, where the mineral appears to be present, as described beyond under M_4, and an acid test for gelatinous silica (chrysolite), where this mineral is also thought to be present. For this latter test ½ gram of the fraction, very finely ground, is boiled with dilute nitric acid, filtered, and the filtrate evaporated. If chrysolite is present gelatinous silica will separate out.

The silicates can often be satisfactorily identified by simple inspection with a lens. Further study of them may be made with the

[1] Brush and Penfield: Determinative Mineralogy.

polarizing microscope. For such examination a small portion of the fraction (0.1 to 0.2 of a gram) is placed on a glass slide and the grains covered with a drop or two of some colorless oil, so as to imbed them in a medium of higher refractive index than air (cedar oil is excellent) ($n = 1.52$). One who has not had experience with the optical properties of silicate grains of varying size under the microscope should prepare sample slides for comparison by crushing up typical specimens of the common rock-forming silicates, sizing the grains to make them comparable with sand grains. It must be borne in mind by one used to studying minerals in thin rock sections, where a uniform thickness is usually obtained, that in a sand where the grains may differ considerably in thickness wide variations in depth of color, absorption, pleochroism, and interference colors may occur between grains of the same material. Since the grains usually exceed in thickness the minerals in a good thin section, the phenomena just mentioned will, in general, appear more marked than in thin section. In the table below are given the main characteristics most useful in readily identifying the common silicates met with in this fraction. For further details a text-book on mineralogy may be consulted.

Mineral	With Hand Lens	Appearance under Microscope
Garnet (of varying composition, but consisting chiefly of the almandite molecule).	Red and pink of various shades. When altered, brownish; rarely yellowish brown or nearly black (altered). Occurs as irregular grains, but more commonly in round grains with dodecahedral and trapezohedral outlines, also frequently as perfect crystals.	In plane polarized light, light pink to almost colorless, clear grains or crystals. Between crossed nicols, usually isotropic, occasionally anomalous.
Epidote (iron-rich variety).	Yellowish green (pistachio). Less common as brownish green and greenish black grains. These are commonly rounded. Often in prismatic forms with rounded ends; fre-	Often shows distinct parallel cleavage lines. In plane polarized light shows distinct and characteristic pleochroism in light shades of yellow, yellowish green, and yellowish brown; rarely reddish. Between crossed nicols shows very strong bire-

Mineral	With Hand Lens	Appearance under Microscope
Epidote (iron-rich variety).	quently shows one perfect cleavage.	fringence. Interference colors white, of higher order where grains are over 0.06 mm. thick.
Hornblende.	Black to greenish black or green grains, often prismatic, and showing lustrous, perfect prismatic cleavages.	In plane polarized light shows marked pleochroism and more or less absorption in shades of green, bluish green, yellowish green, to yellow; rarely brown. Between crossed nicols rather high interference tints, often somewhat hidden by the natural color; extinction at angles of from 0–15° with the cleavage lines, which are usually well marked.
Hypersthene.	Usually square prismatic crystals, sometimes with terminal faces, more often rounded ends. Sometimes as rounded grains. Color, dark brownish green.	In plane polarized light pleochroism marked to strong, parallel to C = c′ = elongation of crystal, green. Parallel to A = a, reddish brown or yellow. Parallel extinction with crossed nicols; low interference tints. Crystals often carry abundant inclusions of magnetite or ilmenite.
Bronzite Enstatite.	Prismatic grains of a light grayish green to olive-green color. Bronzite sometimes shows a bronzy lustre.	Little if any pleochroism; parallel extinction; low double refraction; C = c′ = elongation.
Pyroxene (Diopside, Augite).	Usually dull, vitreous, green, also brownish to black grains, rarely showing any distinct crystalline form.	Color, usually light green. In plane polarized light little or no pleochroism, except in violet-brown colored grains, where it is distinct. With crossed nicols, high interference colors; extinction angle usually large.
Chrysolite (Olivine).	Light green, rounded grains (gelatinous silica test serves to detect this mineral when its presence is suspected).	No pleochroism nor distinct cleavage. Very high interference tints. Extinction usually parallel to crystallographic outlines if these are present.

Mineral	With Hand Lens	Appearance under Microscope
Serpentine.	Light yellow or greenish to dark green, round grains; dull lustre; often with black iron ore inclusions.	Non to semitransparent grains, as described opposite.
Tourmaline.	Black, prismatic, or round grains, vitreous lustre.	Strong absorption and pleochroism, perpendicular to the vertical axis. The prismatic grains give parallel extinction between crossed nicols.
Biotite and phlogopite.	Brown to black plates and scales.	Light to dark brown plates, easily recognized by appearance.
Chlorite.	Green plates and scales.	Green flakes; very low interference colors.
Monazite (probably, also, some varieties of xenotime and related minerals).	Commonly occurs as equidimensional grains retaining some crystallographic boundaries. Possesses a characteristic amber color, often with a brownish or reddish tinge.	Crystalline boundaries often distinct; also good basal cleavage, and sometimes other cleavages or partings. A rich, characteristic yellow or orange-yellow; sometimes reddish or brownish color. Slight pleochroism or absorption. High interference tints between crossed nicols. Extinction nearly or quite parallel to crystal outlines and cleavage.
Allanite (rare)	Brown to black grains.	Red pleochroic grains.
Staurolite (rare).	Brown, sometimes with crystallographic outlines.	Orange to brown pleochroic grains.
Cordierite (Iolite).	Prismatic, rounded grains of bluish color.	Striking pleochroism in shades of blue or violet to yellowish white. Absorption also marked, perpendicular to elongation of prism; parallel extinction. Often shows alteration.
Quartz (Chalcedony, Flint, Jasper, etc.), Feldspar.	Brown, reddish to red (with iron rust), irregular grains.	Often show a white matrix filled with rusty materials, commonly amorphous in appearance.
Rock grains.	Round grains of various dark-colored, compact rocks.	

Nonmagnetic Fraction. M_4. — The more important minerals which may be met with in this fraction are as follows, the most common ones being italicized:

Mineral.	Specific gravity.	Mineral.	Specific gravity.
Quartz (*chalcedony*, flint, jasper, etc.)	2.6 -2.66	Spinel	3.5 -4.4
Feldspar	2.57-2.75	Titanite	3.4 -3.56
Serpentine	2.50-2.65	Diamond	3.51-3.52
Cordierite	2.60-2.66	Corundum	3.95-4.10
Beryl	2.65-2.80	*Rutile*	4.18-4.25
Muscovite	2.76-3.0	(Brookite, octahedrite)	(3.8 -4.01)
Actinolite and *tremolite*	2.9 -3.2	Xenotime	4.45-4.56
Diopside	3.2 -3.38	*Monazite*	4.9 -5.3
Tourmaline	3.0 -3.1	*Zircon*	4.68-4.7
Epidote (zoisite)	3.25-3.38	Thorite	5.19-5.4
Andalusite	3.16-3.26	*Cassiterite*	6.8 -7.1
Sillimanite	3.23-3.24	Thorianite	9.0
Cyanite	3.56-3.67	Other rare-earth minerals ranging from	4.0 -6.0
Apatite	3.17-3.23	Pyrite	4.95-5.1
Topaz	3.4 -3.6	Chalcopyrite	5.7
Garnet (light)	3.4 -3.6	*Light-colored rock grains*	2.6 -3.05

Very often careful inspection with the hand lens will be sufficient to show that this fraction contains no minerals of any technical importance, in which case nothing further need be done with it. In cases of doubt, or where there appears to be some valuable mineral present, a microscopic examination may be made. The writer, however, has found it better, in general, to defer the microscopic examination until the portion has been further fractioned by the use of heavy solutions. An examination of the specific gravities of the minerals listed above will show that quartz (chalcedony, flint, etc.), feldspar, serpentine, beryl, and some varieties of tremolite, diopside, tourmaline, and apatite, are under 3.18. These may therefore be floated in a Thoulet solution (potassium mercuric iodide, density 3.18), and thus separated easily from the others. To accomplish this separation M_4, or a suitable weighed portion of it, is poured slowly, with gentle shaking, into about 10 to 15 c.c. of the Thoulet solution, held in a separatory funnel of about 50 c.c. capacity. The part of the funnel holding the liquid may conveniently have a length of 12 cm., a maximum diameter of

3 to 3.5 cm., tapering downward to a minimum of 1.2 cm. It should have an outlet through the ground glass cock of about 3 mm. After standing until the heavy minerals have all settled they are drawn off, washed thoroughly with water on a filter, dried (weighed, if desired), and a portion imbedded in a drop of oil and examined under the microscope. The portion which floats consists almost always of silica and feldspar or siliceous rock grains, and is of little interest except as regards its relative amount. It would be an unnecessary repetition to give here the microscopic or megascopic characters of all the minerals of this fraction, as most of them are either familiar to all mineralogists or can be readily found in a text-book. A few of the more striking characters, however, which are useful in recognizing at sight the important minerals of the heavy portion, are given in the following table:

Mineral	With Hand Lens	Characteristic under Microscope
Monazite.	Characteristic equidimensional amber-colored grains, often with a brownish or reddish tinge. Crystalline habit well shown.	Color, a clear yellow or amber. Crystalline boundaries often good; basal cleavage good; other cleavages or partings sometimes present. Little if any pleochroism or absorption. High interference colors; extinction nearly or quite parallel to crystal outlines and basal cleavage.
Epidote (can be separated from monazite with barium mercuric iodide solution, sp. gr. 3.55).	Pale yellow to yellowish green grains, usually rounded, sometimes prismatic.	Often shows distinct cleavage lines. In plane polarized light shows distinct and characteristic pleochroism in light shades of yellow, yellowish green, and yellowish brown. Rarely reddish. Between crossed nicols shows very strong birefringence. Interference colors white, of higher order where grains are over 0.06 mm. thick.
Zircon.	Usually as small, highly lustrous, colorless, more rarely red, amethystine or smoky crystals, of square, prismatic habit, often	See opposite. Parallel extinction. Very high double refraction. Interference colors white, of higher order, except in very small crystals. Crystals show very marked dark total reflec-

Mineral	With Hand Lens	Characteristic under Microscope
Zircon.	doubly terminated. The crystal ends are commonly somewhat rounded, but are frequently very perfect. This last is especially true of the smaller sized crystals. Rarely in round grains.	tion borders, due to the strong single refraction.
Titanite.	Colorless, light yellow, brown grains, often with characteristic acute crystal habit.	See opposite. Interference colors as high as zircon; darker colored varieties show pleochroism. High single refraction, with strong total reflection border.
Garnet.	Colorless to pale pink, rarely greenish, rounded crystalline grains. Isometric habit.	See opposite. Isotropic.
Cyanite.	Colorless to light blue or green prismatic crystals.	Colorless or light blue or green (particularly in parts of the crystal). Single and double refraction high. Perfect cleavage parallel to prismatic elongation. Often shows parting perpendicular to this. Extinction oblique to cleavage.
Sillimanite.	Colorless, prismatic, often fibrated crystals.	Colorless, often fibrous crystals; cleavage appears as very fine cracks parallel to elongation; a transverse parting is often seen. Extinction parallel to cleavage ($c' = C$); strong single and double refraction.
Andalusite.	Prismatic, colorless to reddish crystals, rarely transparent.	Crystals are usually filled with inclusions of other minerals, carbonaceous matter, etc. Extinction parallel to the prismatic elongation [$(c = A)$ distinction from sillimanite]. Single refraction high, double refraction rather low. Pleochroism if present is reddish parallel to elongation, green to colorless perpendicular to it.

Mineral	With Hand Lens	Characteristic under Microscope
Rutile (Brookite, Octahedrite).	Red or yellowish brown to nearly black crystalline grains. Rutile prismatic, striated, twinned. The crystalline peculiarities of the three serve to distinguish them.	Deep red by transmitted light. Very high double refraction. Rarely opaque. The striations and twinning of rutile are characteristic.
Cassiterite.	Rounded, opaque, brown or reddish brown grains, often with concentric structure, also lustrous brown, reddish yellowish to nearly colorless crystals.	Commonly opaque. Crystals show high double refraction and relief; colors as noted opposite.
Uraninite (Pitchblende).	Black, pitchy, rounded grains.	Opaque.
Thorianite.	Black cubical crystals.	Translucent, with reddish color, when small or when broken into thin fragments.
Other "earth" minerals of uncertain identity.	Brown, pitchy, or resinous lustre; grains, sometimes with crystalline outlines.	
		Physical Characters
Gold.	Yellow flakes; sometimes show traces of crystalline structure.	Malleable.
Platinum and Paladium.	Whitish steel-gray flakes or nuggets.	Malleable. Hardness 4–4.5.
Iridium.	Silver-white, tinge of yellow.	Less malleable than platinum. Hardness 6–7.
Iridosmine.	Tin to silver-white, steel-gray.	Slightly malleable. Brittle. Hardness 6–7.
Sperrylite.	Tin-white, octahedral or cubical crystals, often showing pyritohedral modifications.	Hardness 5–6. Brittle. Reacts for arsenic when heated in open glass tube; the residue reacts for platinum.
Laurite.	Metallic, iron-black, octahedral crystals or rounded grains.	Heated in the open glass tube, reacts for sulphur, and gives on further heating fumes of osmic oxide.

Mineral	With Hand Lens	Physical Characters
Pyrite.	Light brass-yellow isometric crystals or broken fragments.	Hardness 5.5. Brittle, conchoidal fracture.
Chalcopyrite.	Brass-yellow fragments.	Hardness 3.4. Brittle.
Arsenopyrite and related Arsenides.	Steel-gray to silver-white crystals of isometric or orthorhombic habit, or fragments.	React for arsenic or sulphur or both, and become magnetic on heating before the blowpipe.
Cinnabar.	Bright red, opaque, irregular rounded grains.	Soft; easily volatile when heated in a closed glass tube, yielding a black sublimate which turns red if rubbed on paper.

There is usually no doubt after the microscopic examination as to the presence or absence of monazite. If there is any uncertainty in this regard, or if grains are present which cannot be readily identified, the chemical tests given below are useful. They serve to detect the presence, not only of monazite, but of other rare-earth minerals, and of tungsten and tin.

Monazite, Rare-Earths, Tungstates. — 0.10 to 0.15 gram of the finely powdered grains are moistened in a test tube with three to five drops of sulphuric acid, and heated until the acid has fumed for a minute or two. The tube is then cooled, diluted with 10 c.c. of water, allowed to settle after a good shaking, and the solution decanted through a filter. If monazite, xenotime, or other minerals carrying the rare-earths and decomposable by the acid (and the majority of such minerals are) are present, a white or pinkish precipitate of earth oxalates will be thrown down when 10 c.c. of a saturated solution of oxalic acid is added. The solution should be allowed to stand if small quantities are to be detected. Ammonium oxalate may be used here, but where apatite, calcium phosphate, is present in the fraction, as it often is, there is danger of oxalate of lime coming down here with the excess of the ammonium salt. Furthermore, thorium oxalate tends to dissolve in the hot ammonium oxalate. In this way at least 1 per cent of monazite (and xenotime) can be detected in the fraction M_4. The amount of other earth minerals which can be detected in this way is doubtful. To the residue left in the test tube after the above filtration is now added a few drops of hydrochloric acid and a very small piece of tin, and the acid evaporated. As dryness is approached, if a tungstate

(scheelite) is present, a characteristic blue color appears in the residue. If much tungstate is present the yellow tungstic oxide can be seen before the blue color develops. This blue color might be due in rare instances to the presence of some niobate decomposable by sulphuric acid. If, therefore, a blue color is obtained, any brown or brownish black grains, particularly any with a pitchy lustre, should be picked out, if possible, and examined with especial care. Titanite, when present in considerable quantity, will impart a grayish color to the residue, and although quite different in color from the blue of tungsten it may obscure small amounts of the latter. With allowances made for the presence of titanite, and *very rarely* of niobates, the tungsten test is delicate to a fraction of 1 per cent.

Tin. — Where the presence of cassiterite (tin stone) is suspected, about 0.1 of a gram of the powdered mineral is mixed with an equal volume of charcoal dust and two of sodium carbonate, and fused before the blowpipe on charcoal. When cassiterite is present, even in small quantities, globules of tin can be obtained with the characteristic white, nonvolatile coating of tin oxide. When black grains are present (in the absence of galena) a yellowish coating of lead may point to the presence of uraninite.

Rather rarely pyrite, chalcopyrite, arsenopyrite, and cinnabar may be found here. These can easily be recognized in most cases by their color or crystalline shape, but if any doubt exists a test for sulphur, arsenic, or mercuric sulphide, made by heating some of the grains in a closed glass tube, is sufficient evidence of their presence.

When sands come from regions where active mining operations are being carried on, pyrite and chalcopyrite are not uncommon, and other sulphides, such as galena and sphalerite, may be found. These last are easily recognized at sight.

If, for purely mineralogical reasons, it is desired to make a more extended and exact determination of the minerals present in M_4 or of the silicate portion of M_3, the following lines of investigation have been found useful by the writer.

First. — A careful fractioning with the Thoulet and barium mercuric iodide solution or with methylene iodide may be made, and in rarer instances, where minerals with specific gravities of between 3.55 and 4.5 are to be separated, the silver thalium nitrate double salt[1]

[1] For a full description of heavy solutions and their use see Mikroskopische Physiographie der Mineralien und Gesteine. H. Rosenbusch and E. A. Wülfing. Part I, pp 38–50, ed. 1904.

may be used to advantage. The fractions thus obtained can each be examined chemically and microscopically.

Second. — A determination of the relative or even the actual mean refractive index of particular grains is often of service in the identification. For the relative determinations of the index it is convenient to have several liquids of high, known refractive index. The mineral grains, if very small, otherwise fragments of them, are covered with the liquid and the relative strength of the refractive index of the mineral and liquid determined under the microscope by Beck's method.[1] The actual mean index, if lower than the liquids used, may be determined accurately by diluting the liquid about the grain with some solvent of lower refractive index until the indices are exactly matched. The index of the liquid may then be measured. In practice the relative index is, in most cases, sufficient to furnish the information desired. The following liquids have been found serviceable by the writer:

	n
Cedar oil	1.516
Oil of cloves	1.532
Nitrobenzol	1.554
Oil of cinnamon	1.601
Monobromnaphthalin	1.658
Methylene iodide	1.740
Sulphur dissolved in methylene iodide	1.83

Third. — Where the grains are so thick as to render difficult the determination of the strength of the double refraction. Some of them may be imbedded, along with a little quartz or other mineral of known birefringence for comparison, in melted Canada balsam; and when this has hardened they are ground down on a copper lap or glass plate until a thickness is obtained permitting of accurate comparison with the quartz grains and of study with the quartz wedge or sensitive tint.

Massachusetts Institute of Technology,
Boston, Mass., August, 1906.

[1] For a description of this method see Mikroskopische Physiographie der Mineralien und Gesteine. H. Rosenbusch and E. A. Wülfing. Part I, pp. 263–271, ed. 1904.

SHIP MODEL STATIONS

By CECIL H. PEABODY

The modern competition in shipbuilding, whether for commerce or for war, is so keen that a naval architect cannot consider that he has the correct design for any case unless he has determined the best form of a ship for the required purpose and has accurately apportioned the power to produce the required speed. A failure to obtain the best form will lead to a demand for excessive power, and a failure properly to apportion the power to the speed will lead either to a failure to obtain the desired speed or to excessive weight of propelling machinery, a defect that is equally disastrous if not so immediately evident.

At the present time there is much reliable information concerning ships and their engines in books and periodicals, and it is the habit for governmental and private establishments to systematically record the results of experience, so that they are immediately available for use in making new designs; and yet there is more appreciation than ever before of the desirability of some more direct way of investigating new problems that are continually arising. The most approved method of investigation is to make experiments on models of ships, and to infer from the comparison of the performance of known ships and their models what may be expected from a new design after the corresponding model has been tested. For this purpose experimental stations have been established by the leading maritime nations and by a number of shipbuilders or shipowners, and also at several colleges where shipbuilding is taught. All the stations now established are fully occupied, and it is the opinion of leading shipbuilders that many more could be used to advantage.

The following nations have such stations attached to their navy departments, namely: United States, Great Britain, Germany, Italy, France, and Russia. Two Scottish firms of shipbuilders and one German steamship company have private stations, and another is soon to be installed by a Japanese company. The German station is at Charlottenburg, and its control is divided between the navy and the Technische

Hochschule. The University of Michigan has a station, as has also Cornell University, though it is not known that the latter is fully equipped. During the summer I was able to visit three governmental stations and three private stations; the American station at Washington has been visited several times, but will not be considered in this report except as it may appear proper to make comparisons of the several stations.

Before giving descriptions of the several stations visited, it may be best to give a brief general statement of the methods of testing models and of inferring from such tests the performance of ships. In the first place it may be stated that while the theory of hydrodynamics enables us to study the flow of water past a ship that is under way, and also the forms of waves either in the open sea under the influence of the wind or those made by and accompanying ships, and while such a study is essential to any investigation of the problems before the naval architect, whether experimental or theoretical, that theory does not now and does not appear likely in the future to lead to direct solutions of such problems, on account of their extraordinary complexity. Advance in the science and art of shipbuilding is to be expected from an intelligent observation of the performance of ships and from the use of information thus obtained for new designs. The most potent method for this purpose is the theory of mechanical similitude, which may be considered to be an extension of geometrical similitude to problems of mechanics. An intelligent use of this method, with proper precautions, enables us to infer from the action of a small model what a ship similar to it will do. A most apparent advantage of using such a model is that it may be cheaply made and tested, and that modifications can readily be made; an advantage that is even more important is that the experimenter can have the model completely under his control, and can drive or tow it at any desired speed; and, further, the problems of resistance and propulsion can be treated separately or combined, which is quite impossible under service conditions with large ships. By resistance we mean the force that must be overcome when the ship is driven at a certain speed. The simplest case occurs when a ship (or its model) is towed in quiet water, the resistance being then equal to the pull of the towrope. On the other hand, propulsion of a steamship by paddle wheels or a screw propeller sets in motion a stream of water in contrary direction, which at once disturbs the flow of water past the ship and increases the power that must be applied. It is at once evident that

there is a great advantage in being able to test a model and its propeller both separately and together. It is customary to consider that the towrope resistance (so called) may be divided into two parts: first, the resistance due to the flow of water past the ship, which gives rise to a kind of frictional resistance; and second, the resistance due to maintaining the system of waves that are made by and accompany the ship. Such waves are very evident when any ship is driven at speed, but the form and nature of the waves cannot readily be determined by observations made from the ship or from neighboring objects. In passing, it may be said that a good distant view of the wave can be seen when a ship passes under a high bridge, such as that at the Firth of Forth. It has been proved that the form and location of such waves, where they are in contact with the hull of a ship, have much to do with her resistance, and a study of them can be best made at a model testing station. As for propellers, they can be studied separately only at model testing stations, and such tests have brought order out of chaos, though there yet remains much to do both in theory and practice.

During the design of the *Great Eastern*, William Froude, Esq., was obtained by Scott Russell to make certain investigations by the aid of models to determine the probable behavior at sea of that ship. Afterwards the attention of the British Admiralty was called to his work, and a grant of money was made to establish a station for towing ships' models at Torquay near his residence about the year 1872. Investigations were made at this station by William Froude and by his son, R. E. Froude, who is now the scientific expert to the Admiralty. In the year 1886 a new and improved station was established by the Admiralty at Haslar, just across the bay from Portsmouth. It is not too much to say that the investigations of the Froudes, father and son, have done more for the development of scientific shipbuilding than any other single influence.

It was, therefore, with the greatest pleasure that I learned of the favorable answer to my request to see this station, which had been made through the American embassy, especially as arrangements had been made for me to meet Mr. Froude at that place. The very universal favors that were shown me at that time are to be credited to the kindness of Sir Philip Watts, K.C.B., Chief Constructor to the Admiralty, to whom I was introduced by Professor J. A. Ewing, the Director of Education to the Admiralty.

The station at Haslar is the prototype of all the model towing

stations, and is very closely copied by all other European stations; consequently it will be described at some length, and the descriptions of other stations will give only such features as differ from the prototype. The description must be in general terms to avoid making the report too technical and tedious; as there are excellent detailed descriptions of this station and its details, there is less reason for prolixity.

To provide for towing the models there is a canal or tank 400 feet long, 20 feet wide, and 10 feet deep, with vertical masonry side walls. On these walls are laid steel rails like those of a railway, except that the gauge is over 20 feet instead of the conventional gauge of 4.7 feet. A carriage spans the canal and carries the observers and the apparatus for towing the model and making the proper records. The pull required to tow the model is measured directly by a helical spring, and the deflection of this spring is multiplied by proper mechanism and is recorded on the drum of a chronograph, on which are made also records of times and distances. Since the extreme accuracy of the astronomical chronograph is not necessary for this work, it is found sufficient and convenient to drive the drum by gearing from the axles of the carriage. The time is measured by a chronometer, which beats half seconds and makes and breaks an electric current that operates a pen on the chronograph in the usual manner. Along the side of the canal are electric contact pieces at regular distances that enable the carriage as it passes to make an electric circuit and make a record on the chronograph which, with the time record, gives the means of determining the velocity of the carriage. There is also a device for determining and recording the change of trim, that is, the rise of the bow and depression of the stern, that usually takes place when a boat is driven at speed.

The carriage at Haslar is made of pine wood, so arranged in the form of hollow box girders as to be at once very light and stiff. It is towed by a wire rope, which is wound up by a steam engine with a special governor, devised by William Froude, to bring the engine quickly to its desired speed and to maintain a uniform speed. Having found that the longitudinal elasticity of the wire towrope gave rise to troublesome oscillations, a hydraulic cylinder and piston were interposed to act as a dampener.

The free course of the carriage is reduced by necessary arrangements at the ends for convenience in adjusting the model and the

carriage to 380 feet or less, which at some speeds is traversed in about twenty seconds. The carriage must be quickly brought up to its proper speed in order to give a reasonable time for making records and for stopping safely at the end. In preparing for a test, the probable pull on the spring is estimated and stops are set wide enough apart to give necessary freedom and provide for oscillations, but near enough to avoid undue extension and violent oscillations. While the carriage is started a rigid stop is thrown in which carries the pull required to accelerate the model, and this stop is not thrown out till uniform speed has been attained.

To arrange for testing propellers a second carriage is provided, which can be attached behind the towing carriage with devices for measuring the turning moment applied to the shaft of the propeller, the number of revolutions per minute, and the thrust due to the action of the propeller on the water. A proper chronograph is provided for recording these several actions. If the ship model is omitted, experiments can be made on the propeller in undisturbed water; with the model in place and the propeller properly related to it, the interaction of ship and propeller can be investigated.

It is needless to say that apparatus must be accurately made, delicately adjusted, and skillfully used in order that valuable results may be obtained.

The models are made of paraffin, with the addition of 3 or 4 per cent. of beeswax, as that substance is readily molded to an approximate form, is readily cut to the exact shape, and may be burnished to a smooth surface which is not affected by water. In preparation for casting a model, a mold is made in modeling clay which is about $\frac{1}{4}$ inch larger than the finished model. A kind of canvas canoe is made to determine the inner surface of the model, leaving a thickness of about $1\frac{1}{2}$ inches to be filled with paraffin. The cotton cloth of this canoe is painted with modeling clay to prevent flow of hot paraffin through it, and then melted paraffin is run in slowly, there being considerable shrinkage on cooling, which must be made up by running in additional paraffin. As the mold is filled, water is run into the inside of the canoe to counteract the hydraulic pressure of the paraffin and to aid in cooling. The model is carried to a convenient height above the level of the water line at which it will float, and is finished at the top to a plane surface, with four projecting lugs on each side to aid in determining the draught and trim of the model when ready for testing. For this purpose hook

gauges are hung in pairs on the two corresponding lugs on the port and starboard sides, by aid of which the adjustment to the proper level can be made with great accuracy. The model is cut in a profiling machine resembling a planing machine, with a table that can be traversed back and forth under a frame which supports a pair of revolving cutters. These cutters are much like those used for cutting wooden moldings, but the edges are keener, and they are driven at very high speed, as they operate on a soft material. The model is properly centred on this table, and the cutters are adjusted to the height of a "water line," or horizontal section; then they are guided in such a manner as to cut a groove on each side down to the proper surface of the model as it is moved with the table past them. The redundant material is afterwards pared away by a skillful model maker, and the surface is faired and smoothed to the correct form. The device which was invented by William Froude for tracing water lines is worthy of description, as it is simple and effective. In the first place, it may be premised that the cutters can be simultaneously drawn together or moved outward from the centre line of the model by turning a handwheel conveniently placed at the side of the machine. This motion is communicated to a pantographic device which moves a tracer over a drawing of the water line of the ship (usually on a smaller scale than the model), which is pinned to a drawing board which reciprocates with the model, but at a slower speed commensurate with the reduced scale of the drawing. As the cutter is a circle, the tracer is also a circle drawn to the scale of the drawing. Starting at the middle of the model, the operator draws the cutters together till the tracer touches the proper water line. He then starts the table of the machine, and as the drawing board moves under the tracer he continually draws the cutters nearer, keeping the tracer in contact with the water line, and thereby profiles the groove for that water line from the middle to one end of the model — the bow, for example. Returning to the middle, he performs a like operation for the stern. There are two very ingenious devices to ensure correct and certain action of these cutters. In the first place the drawing, however carefully made, may not have its base line, as pinned to the board, exactly straight; consequently a wooden straight edge is clamped on to the base line and bent to conform to any slight inequality it may have. Then the pantograph is made with two parts, one of which bears against the wooden base line and the other carries the circular tracer; consequently the operator is virtually meas-

uring the half breadth of the model (which is not likely to be affected by handling the drawing) and transferring it to the cutters. Should the operator fail to trace the line correctly, it is most likely that he will leave redundant material which can be removed by tracing the line again, or it may be cut away by the model maker. To give more complete control the table is not driven directly from a source of power, but is driven by a hydraulic device which continually pumps water through an open valve. The operator may close this valve at pleasure by pressure on a foot lever, thereby producing pressure on a piston which actuates the table at any desired speed. The operator has, therefore, complete control over the cutters and the table, and can work as fast or as slowly as he desires; and if he hesitates he probably does no more than fail to cut deeply enough, a defect that he may remedy immediately by reversing and tracing over again. Being allowed to try the machine, I found that a little practice was sufficient to give decent execution, and I am convinced that the method gives all needed accuracy. In fact, it was stated by an attendant that the error was commonly not more than one-tenth of one per cent.; he thought that three-tenths would be "a lot."

Experimental propellers are made of an easily fusible composition of lead and tin, with a little bismuth. They are conveniently made by first preparing a true helical surface of plaster of Paris; on this the contour of the blade is drawn, and the blade, with proper thickness, is molded in wax. The plaster is set with the helical surface uppermost, and liquid plaster is poured on and allowed to harden; when the two blocks of plaster are separated and the wax blade is removed there will be in hand the two halves of a mold for casting the blade. Clearly two, three, or four blades can be prepared in the same way, and the assembled molds, with provision for the hub of the propeller, can be used for casting an entire propeller. The surfaces of the casting are scraped smooth, but the form is changed as little as may be. The contour of a blade, as drawn on the true helical surface, is an ellipse (as nearly as the circumstances admit) for propellers of usual proportions. Where very large blade surface is demanded, as for torpedo boats, to avoid discontinuity of the water acted upon by the propeller, the blade is widened at the end and approaches the early form with straight edges, such as is commonly used for towboats. The elliptical form has been shown as the standard by the British admiralty. The American Navy Department has selected a form that is somewhat more rounded at the end.

Experiments on propellers at Haslar show that when driven in open water much loss of efficiency is felt if a large hub is used. Adding a headpiece does not much reduce this difficulty. But propellers on ships do not lose efficiency in like proportion when large hubs are used, because the water is guided to the propeller by the form of the ship, including the bosses surrounding the propeller shafts.

One of the most important series of problems affecting propulsion is the investigation of the wake (or stream of water dragged along with a ship by friction against the sides of the ship), the effect of this wake on the efficiency of the propeller which works in it, the disturbance of this wake by the propeller itself, and finally of the best arrangement of the propeller for a certain ship. From what has been said it will be seen that an experimental tank gives opportunity for investigating these problems for a model. Unfortunately the conditions are not exactly the same for a ship and its model when towed or driven at corresponding speeds, especially as the model has much more wake than the ship, as is shown from comparison of progressive speed trials on a ship and tank tests of her model. For sake of comparison it is customary to draw wake diagrams for the ship and her model in a method that cannot be adequately described here. It is sufficient to say that such diagrams are found to be similar, though not similarly placed, and that a comparison of the diagrams for a certain ship and her model allows a skilled observer to infer from the diagrams of a model what the conditions for a ship built on that model will be. Mr. Froude thinks that, on the whole, the comparison is as good as such a method warrants, and is a reliable guide for determining the problems of speed and power.

It has long been known that forms that are adapted for high speed in smooth water may not be seaworthy or (even if quite safe) may not give the best speed in rough water. This fact has been considered by some shipbuilders to cast doubt on the value of model experiments, and also on progressive speed trials, which are always made in smooth water. In order to investigate the effect of rough water on speed, Mr. Froude has made experiments on towing a model of a cruiser among artificial waves in the experimental tank. It may be sufficient to say that he finds that for a cruiser the best results are obtained by so drawing out the bow as to give a slight hollowing of the water lines It should be remembered that all warships carry their guns at a considerable height above the water, and for that reason must be given

greater beam than have merchant ships, which carry their principal weight in the hold. Consequently the conclusion which holds for cruisers may not hold for passenger ships. The model which was tested under the given conditions was seen at Haslar, and the apparatus for making waves was in place and was set in operation to exhibit a number of interesting features of the waves made by it.

By the trochoidal theory of waves each particle of water is assumed to revolve in a fixed orbit; the orbits are assumed to decrease in diameter rapidly with the depth below the surface of the water; it is also assumed that all the particles which have the centres of their orbits in a vertical line revolve together and come to the tops of their orbits (or any other corresponding parts) at the same instant. A curve drawn through corresponding points of such a set of orbits is called a dynamical vertical. If a model were made to revolve a series of points in properly arranged orbits, and if a slender rod were passed through those points, that rod would be seen to wave back and forth, something like a stalk of grain in the wind, though the comparison is far from exact. Such a rod would represent a dynamical vertical. Now Mr. Froude has placed a wooden frame or diaphragm about 2 feet wide across the further end of the tank, and has arranged cranks and rods to give the frame a motion approximating to that of a dynamical vertical of the wave he desires to produce.

When this apparatus was started the waves showed a series of surface wrinkles or surface tension waves; the peculiarity of these waves is that the faster they run the shorter they are, and short waves are rapidly dissipated by viscosity; therefore when the apparatus was well under way at its proper speed the wrinkles disappeared. If the apparatus was run a short time and then stopped it generated a group of waves; one could easily walk along with the group and determine the fact that the velocity of the group was approximately half that of any individual wave. The apparatus was then set to give waves that tended to run up to a head and break, and observation showed that the crest just before breaking had a sharp edge like the roof of a house, the angle at the apex being about 120°. These three several phenomena all agree with the hydrodynamic theory of waves. It was most curious and interesting to note that an attempt to make a trochoidal wave resulted in forming a wave which at its maximum height had a crest with an angle of 120°, as is shown by Stokes to be proper for an irrotational wave, the more so as mathematicians object to the

trochoidal theory of waves, inasmuch as it is rotational and therefore cannot be generated by weight and pressure only as sea waves are supposed to be. It is further interesting to remember that the form of sea waves is much more like a form deduced mathematically by Stokes for irrotational waves than they are like trochoidal waves. However, the two forms approach as the heights decrease, and with moderate heights are hardly distinguishable.

The water for filling the tank was taken from the local town supply, and is renewed only to make up losses by evaporation and otherwise. The first summer after the tank was established there was a very annoying growth of weeds. Each succeeding year the growth diminished, though nothing was done to that end, and now the growth is not troublesome.

The second experimental model station to be established was that at the Leven shipyards, at Dumbarton on the Clyde. It is now the oldest station, as it was established in 1884 on the model of the original station at Torquay; this, together with the fact that it was the first station for private work and the fact that it has since been used uninterruptedly, gives it an unusual interest. Its dimensions are: length, 300 feet; breadth, 20 feet; draught, 8.8 feet. Like the Torquay station, the rails for the carriage are slung from the roof, and they have a gauge of only 4 feet. The carriage is drawn by a wire rope, and there is no apparent intention of substituting electricity. The carriage being very light, there is no difficulty from longitudinal oscillation of the rope, which is attached directly. By the aid of this station the firm has the more easily taken a leading position, especially in certain difficult fields, like the building of high-speed paddle steamers and the application of steam turbines. In 1888 the firm desired to bid for a paddle steamer 300 feet long and with a beam of 35 feet, which was required to make 19½ knots (at the time an exceptional speed), and in order to have an advantage wished to increase the speed to 20½ knots. At first the scientific staff were unwilling to undertake a higher speed than the specifications called for, that is, 19½ knots; but, after trying a number of models in the tank and changing proportions of the hull and the arrangement of the paddles, they concluded that it would be safe to guarantee 20½ knots as the firm wished. In fact, they found that a better speed could be expected, and their conclusions were verified on trial of the ship, which made the unprecedented speed of 21.6 knots.

The records of the station include a vast amount of information, which is very properly considered to be a part of their stock in trade, and which is not available to the profession in general. A member of the firm expressed the opinion that every important firm could profitably maintain a station for its own work, and that such a station would have little time for outside work even if there were no objections to such use of the station; in fact, he thought they could keep a second station busy if they had it. This opinion is quite contrary to the idea that an open or public station should be maintained by the government or in connection with a technical college, at which models for various shipbuilders could be tested. Such a station, however, was favored if it could be employed in general scientific work that should be useful to the entire profession. For example, it could determine the best form of lines for various proportions and speeds, a piece of work which must now be undertaken by each station on installation before it is in condition to attack special problems advantageously. At one station, which has been more recently installed, such work is in progress and must take much time and energy which could be more profitably employed if general information of that nature were in possession of the profession in general. The investigation of propellers, their proportions, and their efficiencies has been carried out many years ago at Haslar and more recently at Washington and at Cornell. In passing, attention can be called to the fact that a properly equipped station at the Institute of Technology could at once undertake such scientific work to advantage, and would probably be able to get enough work from shipbuilders to enable it to keep the proper correlation with the performance of full-sized ships, and thus avoid any chance of wasting effort in barren academic investigations.

The second governmental station visited was that belonging to the Italian navy situated at Spezia. It was installed in 1889 and differs from its prototype at Haslar only in minor details. In particular, the instrument maker has substituted brass and steel for wood in places, and has produced apparatus which at first sight looks like an improvement, but second thought leads to the question whether the earlier construction under the eye of those who developed this method of investigation, and who could not have lacked means for such construction as they preferred, has not good reason in every case for the material preferred.

A large amount of excellent work has been done at this station, and

much liberality in publishing has been allowed. In the first place we have "La Vasca per le Esperienza di Architecture Navale," etc., by Colonel Giuseppa Rota, a copy of which was presented to the Institute of Technology and is now in the library of the department; and other tests, notably on the effect of shallow water on resistance, have been published by the same author in the *Transactions of the Institution of Naval Architecture of Great Britain.*

As this station is exposed to much the same climatic conditions as are found at the Washington station, it is very interesting to find that they use paraffin for models without difficulty. Of course the models are kept immersed when not in use, as is always customary when paraffin is used. Captain Bonfiglietti, who was stationed at Spezia when that place was visited, expressed the opinion that the real difficulty in the use of paraffin was experienced when the models took large dimensions, like 20 feet in length, and it arose from unequal expansion of the under and out of water parts. This statement may be compared with the practice of using models made of paraffin, 21 feet long, at Berlin.

The method of making propellers at this station differs from that already described in connection with the description of the Haslar station. Here they begin by making drawings of the propellers to a convenient large scale, including transverse sections of the blades. These drawings are reduced photographically to the proper size for the model propellers. Wooden models are then made from these reduced transverse sections, and these models serve for molding and casting the propellers, which are made of the customary composition of lead, tin, and antimony. The models are finished by hand, and are tested by aid of a surface plate and a surface gauge under a magnifying glass.

Perhaps owing to the climatic conditions much trouble was formerly experienced from the growth of weeds, but that trouble has been entirely avoided by the use of copper sulphate in the proportion of one to three hundred thousand.

The carriage at this station is drawn by a rope, just as at Haslar, but there is a proposition to substitute electric motors.

The North German Lloyd Steamship Company have a model towing station at their principal harbor, Bremerhaven, which was installed in 1900, and which has been used primarily for determining the best forms to be given to their new high-speed passenger ships; but it has also been used for investigations of models of warships for almost all the Continental maritime nations, including Russia, which has a station

established thirteen years earlier. The carriage at this station is framed of vertical steel tubes and diagonal tie-rods, and appears to be both light and stiff. It is driven by electric motors, there being two of 6 horse power each. The station is maintained in excellent condition, and the work appears to be thorough and systematic, as might be expected in Germany. The fact that the work has been for governments and for certain private firms explains why there has been little published from this station.

At Charlottenburg, near the Technische Hochschule, there is a station which is owned in common by that institution and the German Admiralty, the navy having exclusive control during a certain part of the year. At the time when this station was visited it was under the control of the navy, while my introduction through the proper channels was to the school. On proper explanation the attendants in charge allowed me to see the work in progress, which was the determination of resistance of a ship in a shallow, restricted channel like a ship canal. They had an apparatus for testing four screw propellers simultaneously; it was said to have proven to be satisfactory, but no encouragement for careful inspection was given. As this station was completed in 1902, and has had the disadvantage of double ownership, it may not be reasonable to expect much in the way of published results as yet.

Paraffin models are used at this station, having lengths as great as 21 feet, though at Haslar and at Spezia lengths greater than 12 feet are deprecated either on account of the weakness of the material or its tendency to soften at high temperature. Summer temperatures at Berlin are liable to be high, though continued heat is not so likely as at Spezia or Washington.

The tank or canal at all the four stations previously mentioned is nearly rectangular in section, there being only a slight concavity of the bottom or rounding of corners But at Charlottenburg the bottom is much rounded, being about 11½ feet deep in the middle and only 6½ feet deep at 10 feet from the middle; from this point of the section the contour is somewhat irregular, but there is in effect a bench at each side 6 feet wide on which the mean depth of the water is only 4 feet. The rails for the carriage are carried by columns at intervals, which has been found to be undesirable, and side walls are to be carried up under the rails, which will reduce the maximum width from 34.5 feet to 20 feet.

The carriage is made of small angle framing and appears to be

light and stiff. It is towed by a separate motor carriage in front, which carries two 10 horse power motors.

The last model station seen was that established at the yard of John Brown and Company at Clydebank, in 1904. It follows the dimensions and construction of the station at Haslar very closely, the principal difference being an appreciable increase in length. A considerable part of the work of the station to the present time has been the accumulation of stock in trade, and there is yet much work of that sort to be done which might have been avoided in large part if such material were published.

Though the experimental model basin at Washington belonging to the Navy Department was not seen this past summer, it may not be out of order to speak of it in this place. It was finished in 1898, and has since done much important work for the determination of the best form for our naval vessels, and there have been most important investigations of the action and efficiency of the propellers, which are more complete and on a larger scale than any similar work. It is not too much to say that when the data with regard to propellers is completed and systematized it will replace all other work of that nature. As for the work on models of ships for the navy, it is reported that the saving from the reduction of engine power for one class of battleships in consequence of improvements in form was enough to pay for the entire station.

The station is under the direction of Naval Constructor D. W. Taylor, U.S.N., the work of observation being carried on by Messrs. Curtis and Hewins, alumni of the Institute of Technology from the department of Naval Architecture.

The station has been described in the *Transactions of the Society of Naval Architects and Marine Engineers*, in which are found published results of investigation made there. It may be sufficient to say that it has been built in the most thorough manner, with every appliance for refined investigation. For various reasons it was decided to make models of wood instead of paraffin, especially as the models are all about 20 feet long, or about twice the length that had been previously used. The method of forming the models is quite different from that used for paraffin models, involving the construction of an entire, full-sized model, with sections and planking much like a carvel-built skiff, which model is used as a former for the profiling machine which cuts the model to be used in the tank.

When possible, tests are made for such private firms as may desire such work, the charge being as near as may be equal to the expense incurred by the station. Such work is, however, limited, because the work for the Navy Department and on scientific investigations which are considered essential for the prosecution of that work keep the stations well employed.

MODERN FLOATING DRY DOCKS[1]

By CIVIL ENGINEER A. C. CUNNINGHAM, U.S.N.

General perfection in floating dry docks was reached with the type first and still known as the "balance dock," which is also called the "solid dock" since the introduction of sectional and self-docking docks. The sketches in Diagram 1 show a plan, end, and side elevation of a

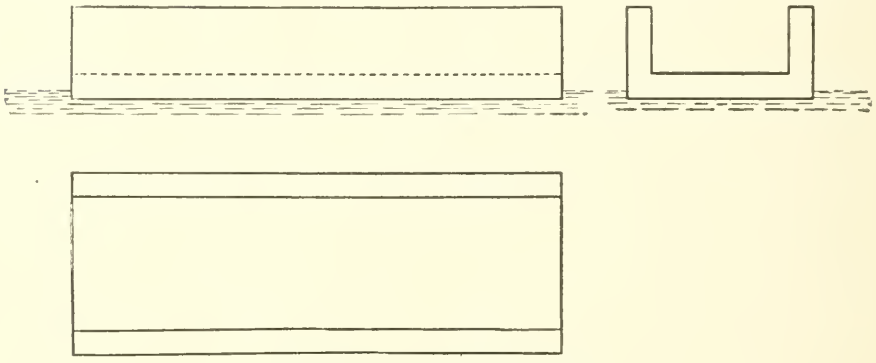


Diagram 1.—The Solid Dock

balance, or solid, dock. In pumping up one of these docks, the trim may be maintained by regulating the amount of water retained in the side walls, which gives the name "balance dock."

These docks were originally and are still constructed in wood, and the inner faces of the side walls are generally given a batter to secure greater transverse stiffness of construction. In wood construction the dimensions and capacity of a solid dock are comparatively small on account of the weakness of the connections and limited strength which naturally accompany the material.

The general cross section of the balance dock has prevailed through all subsequent forms of floating docks of recognized merit, and the more

[1] A lecture delivered before the class of Naval Architects at the Massachusetts Institute of Technology in March, 1906.

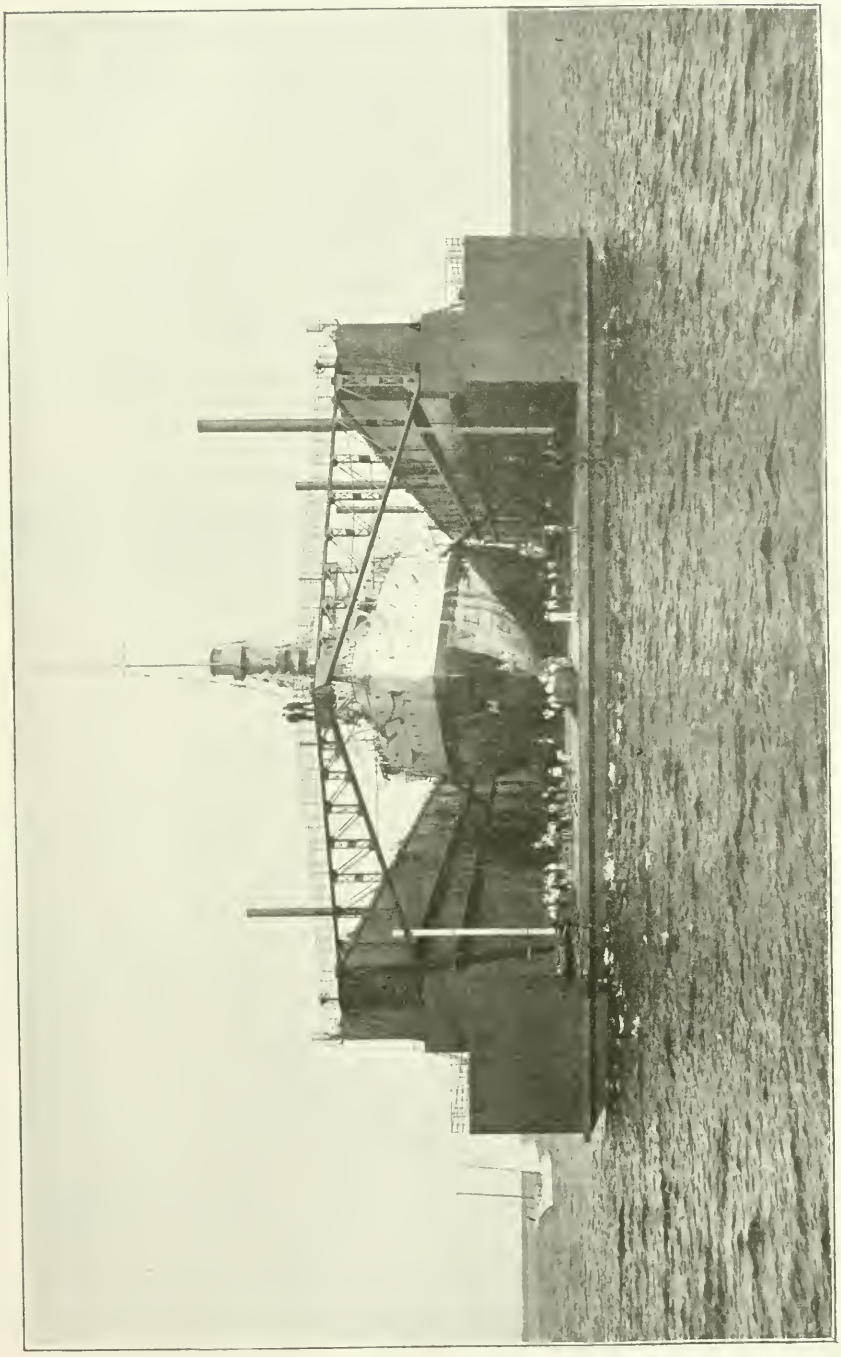


PLATE I. — U. S. FLOATING DRY DOCK "DEWEY," WITH THE BATTLESHIP "IOWA" COMPLETELY DOCKED

closely a modern floating dock approximates to the original balance type the greater its value.

When a solid floating dock reaches dimensions which prevent its entrance into a land dock for repairs, its life becomes limited. In wooden docks this life is of sufficient extent to return a profit on the investment, but it would not be with a steel dock.

The solid dock was closely followed by the sectional dock, which is simply a series of small solid docks loosely connected together merely to preserve the alignment. The advantages of the sectional dock are that one section can be repaired upon another and, in wood construction, a much longer dock can be made operative than would be possible with a solid dock of the same material; an incidental advantage is that the sections may be divided into groups.

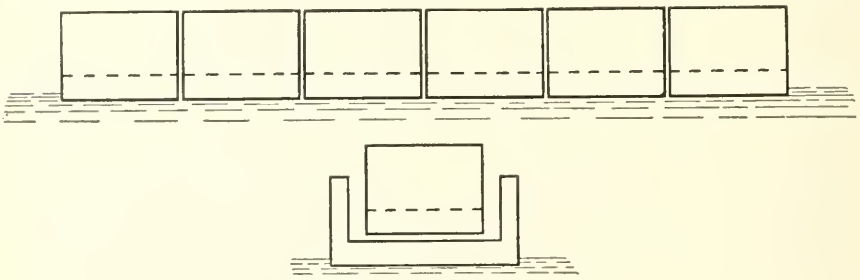


Diagram 2.—A Sectional Dock

In Diagram 2 is shown a side elevation of a sectional dock of six sections which can be subdivided into various groups for independent use at the same time, and also a sketch showing one section turned 90° and docked on another. The disadvantages of a sectional dock are the great care necessary to preserve the alignment and the difficulty of so adjusting the lifting force of each section that the docked vessel shall not be unduly strained or injured. No solid or sectional docks of any extensive magnitude have been constructed of wood.

Diagram 3 shows a modified form of sectional dock in steel construction. Figure 1 is a side elevation of the dock in alignment ready for operation. Figure 2 shows one section docked on the others. A notable dock of this construction is that of Blohm and Voss, in Germany, which has a lifting capacity of 17,500 tons.

From the elevations it will be seen that this sectional dock in steel lacks continuity, and that the self-docking of the sections is a rather precarious proceeding.

The construction of floating docks of any great magnitude in iron or steel requires that it should be possible to have access to the under water portions for preservation and repairs. This led to the development of the general type known as self-docking floating dry docks. As the modern ship of the first class, and especially the warship, is a flexible and tender structure as compared with its short, broad predecessor in wood, it was necessary that these self-docking docks should have the greatest possible continuity and longitudinal stiffness. The sectional dock, pure and simple, has, in consequence, been eliminated from the problem, and an approximation to the solid or balance dock is always sought.

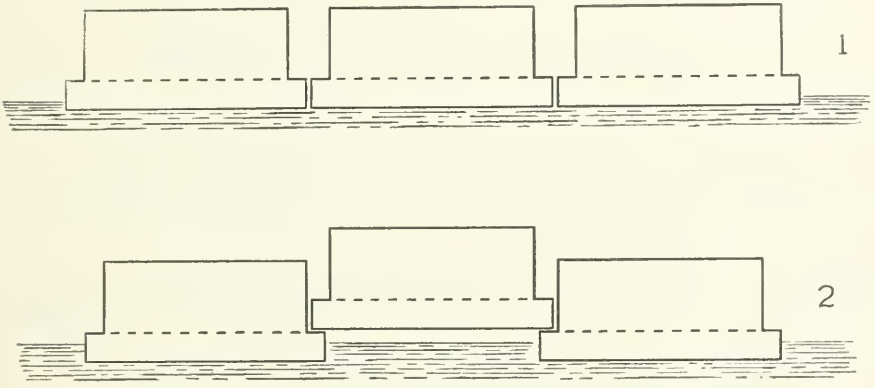


Diagram 3.—A Sectional Dock of Steel Construction

The first self-docking dock of any note that is still of importance is known as the Rennie dock, after Mr. George B. Rennie, the celebrated English engineer.

The Rennie dock is illustrated on Diagram 4. Figure 1 is a plan showing a pontoon being withdrawn preparatory to self-docking. Figure 2 is a sectional side elevation showing a pontoon self-docked. Figure 3 is an end elevation showing a pontoon self-docked.

This dock is a compromise, having the side walls of a solid dock and the pontoons of a sectional dock. For very great longitudinal stiffness the side walls must be unusually high and wide, as any extensive or strong connections between the pontoons are impracticable. The dock has the advantage of being easily constructed; the pontoons can be built and launched separately, assembled after they are afloat, and the side walls then erected on them in place. The self-docking is simple in principle and requires no technical skill or instruction.

The pumping of a floating dock is accomplished with centrifugal pumps, which should be placed as low down in the structure as possible, in order that they may not lose their priming in the last stages of pumping. These pumps discharge directly outboard at their own level. As regards pumping plant, the Rennie dock is at a disadvantage. For economical construction the pumps must be placed in the side walls above the pontoons, and therefore have a long suction in the last stages of pumping, which, if necessarily stopped, may lead to a loss of priming which may be difficult to restore.

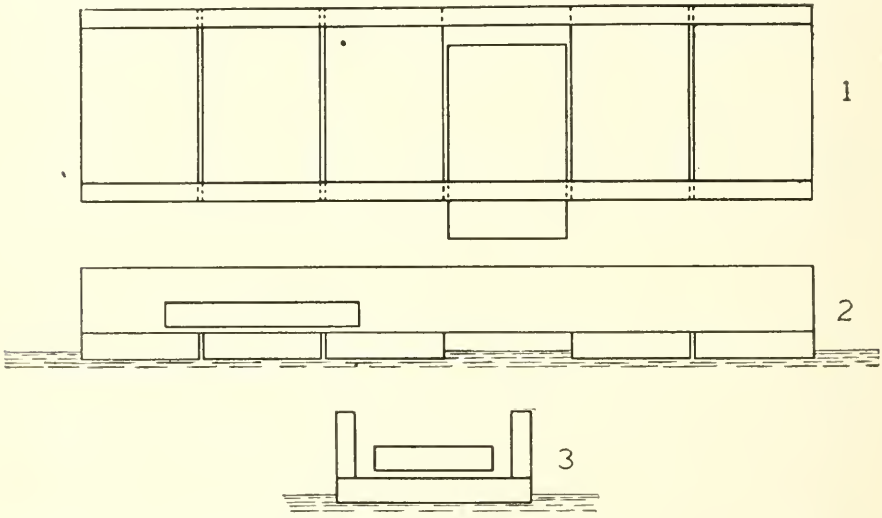


DIAGRAM 4.—THE RENNIE DOCK

A number of important docks have been built on this principle; others are under construction and design in Europe, and the type will always be of importance on account of the ease and simplicity of construction.

The next dock requiring consideration is the Clark type, designed by Mr. Lyonel E. Clark, of the firm of Clark and Standfield, of London. The members of this firm are both descendants of a line of celebrated floating dock designers and builders, and have done more towards advancing the interests and value of floating docks than any other individuals in the world.

The Clark dock is a modification of the Rennie dock, and is illustrated in Diagram 5. Figure 1 is an end view, in which it will be seen

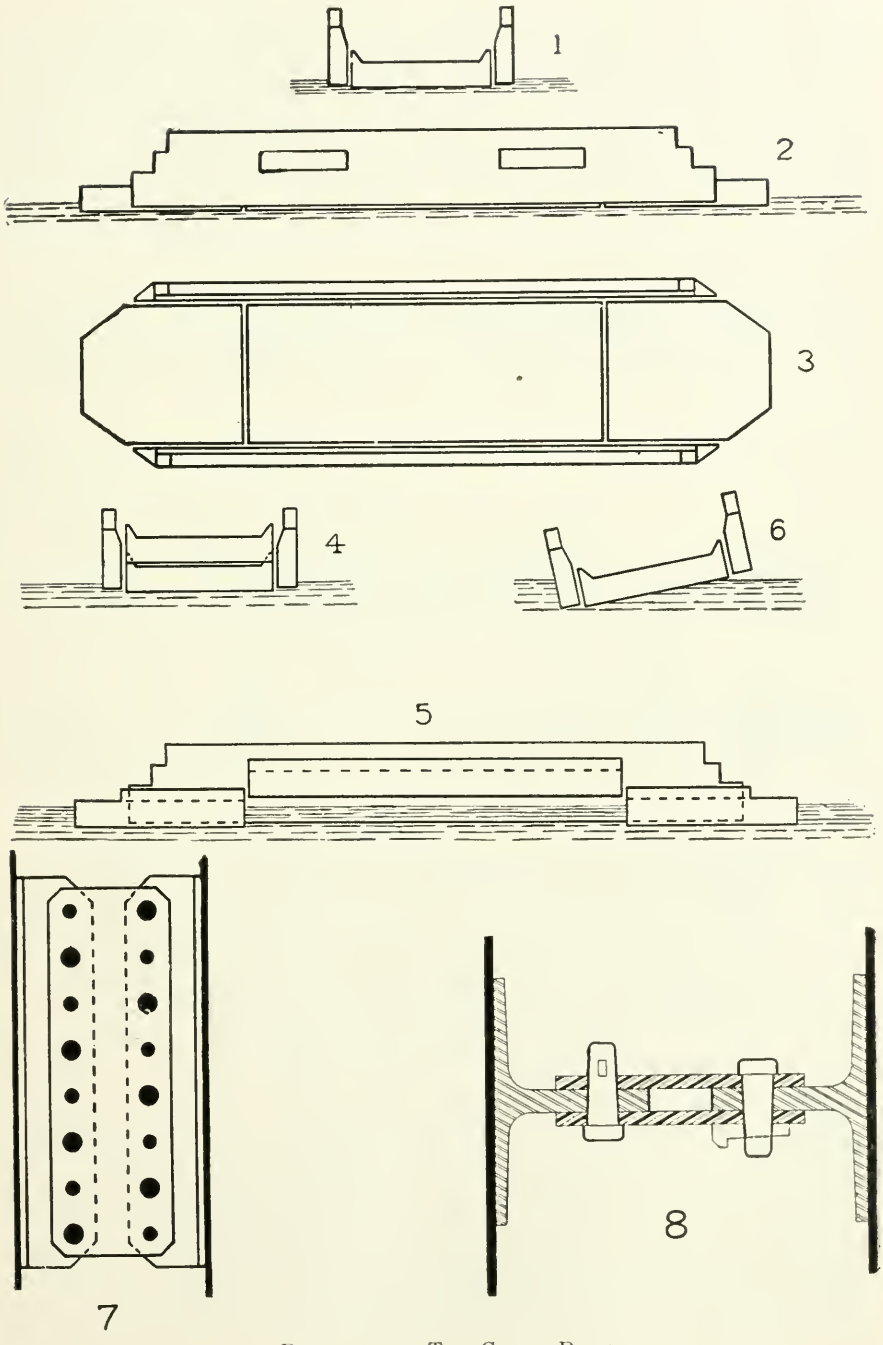


DIAGRAM 5. — THE CLARK DOCK

that the pontoons are placed between the side walls instead of under them. Figure 2 is a side view showing the manner of stepping back the side walls and the gangway openings to which Mr. Clark has so far generally given preference. Figure 3 is a plan showing the pointed end pontoons preferred by Mr. Clark. Figure 4 is an end view showing the end pontoons self-docked. Figure 5 is a sectional side view

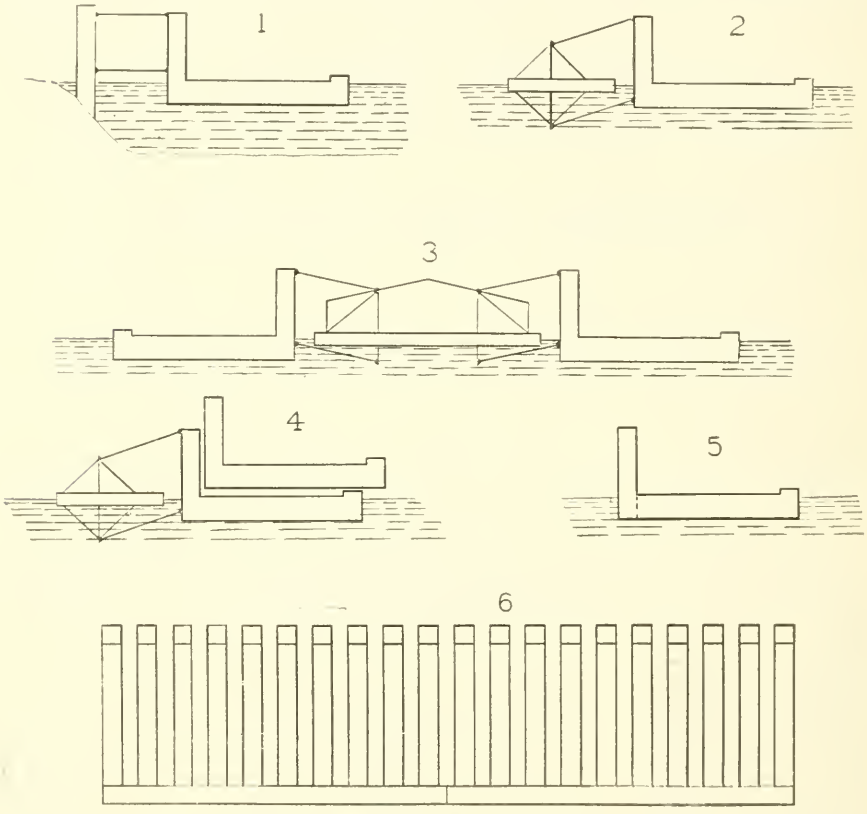


Diagram 6. — Off-Shore Dock

showing the central pontoon self-docked. Figure 6 shows the manner of getting at the bottom of side walls. Figure 7 is a detailed elevation, and Figure 8 a detailed plan of the numerous taper-bolted tee and fish-plate connections between the pontoons and side walls.

In this dock Mr. Clark has sacrificed the simplicity of construction and ease of self-docking of the Rennie dock to securing greater longitudinal strength and stiffness with practically the same material.

It is apparent that for Clark and Rennie docks of the same general dimensions the increased depth of side wall in the Clark dock gives much greater longitudinal stiffness. In the earlier Clark docks five pontoons were used, so that there was not much gain in continuity of floor over the Rennie dock; but in later designs Mr. Clark has reduced the pontoons to the least possible number — three — so that with the long central pontoon the Clark dock has a much stiffer and more nearly continuous floor than the Rennie dock. In the pumping plant Mr. Clark also has the advantage of having the pumps located well down near the bottom of the structure. In locating the pontoons between the side walls the lower connections have been placed in a position where they are normally under water and inconveniently located for inspection and preservation. To bring the upper connections to a suitable height, altars must be added to the pontoons, which decrease the floor space and complicate the construction.

The self-docking of a Clark dock requires skill and technical knowledge. The connections being all in vertical shear, the various combinations of side walls and pontoons used in self-docking must all be brought to the same flotation and buoyancy before the connections can be opened. The accumulations of mud in the pontoons and marine growth on the outside constantly vary the flotations of the separate parts, and the cantings of the dock for partial and progressive openings of connections make it desirable that the self-docking should be under technical supervision.

Another type of dock designed by Messrs. Clark and Standfield is called the "one-sided" or "off-shore" dock. The dock may be attached to a floating outrigger or to a framework on the fore shore by booms having a parallel-ruler motion. It is generally made in two sections. The dock is illustrated in Diagram 6. Figure 1 is an end view of the dock attached to a framework on the fore shore. Figure 2 is an end view of the dock attached to an outrigger. Figure 3 is an end view of a proposed double dock of this type with floating outrigger between. Figure 4 shows the simple method of self-docking. Figure 5 is an end view of a modification of this dock, called a "depositing" dock, with which a ship is lifted and placed upon a grid. Figure 6 is a plan of the depositing dock. The one-sided dock is well suited to ships having considerable inherent stiffness and no greatly concentrated weights. It is very convenient in narrow streams, as the ship can be taken on sideways. No shoring is possible on the off side, and in

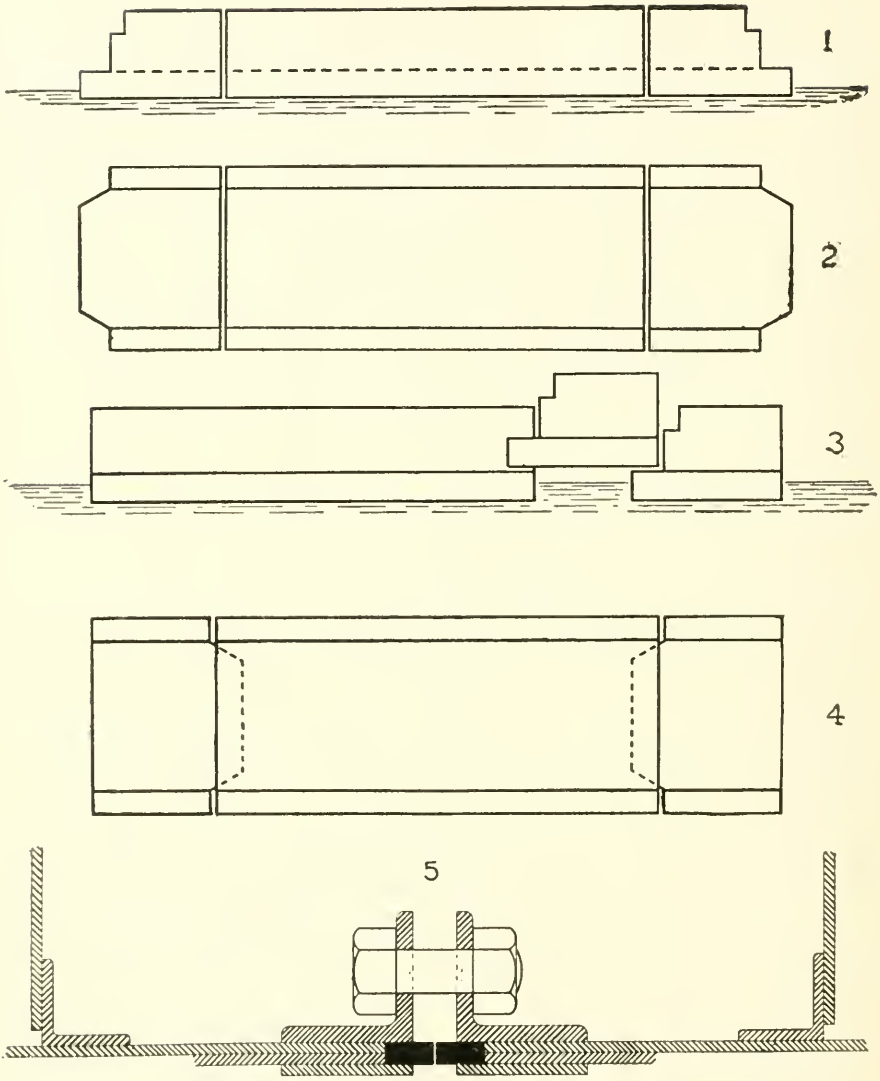


Diagram 7.—Bolted Sectional Dock at Pola

pumping up, care must be exercised to prevent a side launch or rolling over.

These one-sided docks cannot safely be used without their shore attachment or outrigger, as the omission of one side wall destroys the "balance" property. As soon as the pontoons are submerged, the shore attachment must be depended upon to preserve the trim, as

slight variations in buoyancy are not resisted and controlled as in the case of a two-sided dock. For the same reasons the pumping must be done uniformly and with care, in order not to cause a dangerous strain in the shore connections.

The latest design of self-docking dock made by Mr. Clark is a bolted sectional type for the Austrian Naval Station at Pola. This dock

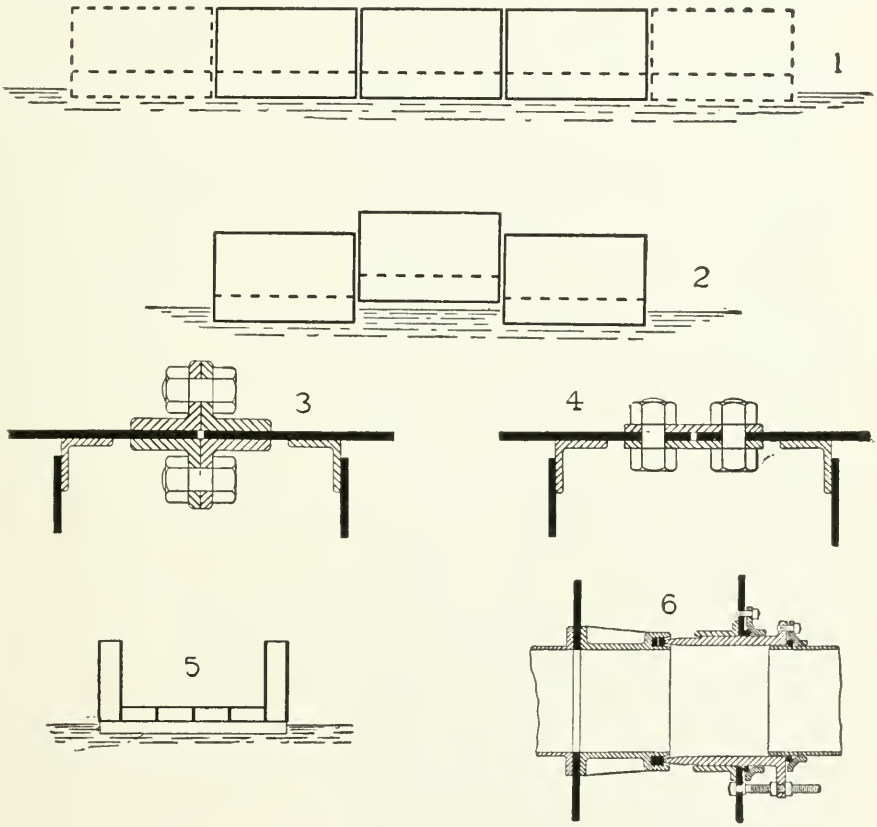


Diagram 8.—The Cunningham Sectional Dock

is illustrated in Diagram 7. Figure 1 is a side elevation. Figure 2 is a plan. Figure 3 is a sectional side elevation of an end section self-docked. Figure 4 is a plan of the central section self-docked. Figure 5 is a detail section of the chamber between sections which extends continuously around the sides and bottom.

The location and extent of the connections between the sections of

the dock make it practically continuous and the nearest approximation to a solid dock that has yet been devised. This dock has not yet been self-docked, so far as can be ascertained, and considerable doubt exists as to the possibility of making or keeping the chambers between the sections dry, so that the connections will be accessible.[1]

The self-docking of this dock is very similar to that of the modified sectional dock first described, except that, owing to the necessarily pointed ends of the end sections, less stability is secured.

The self-docking docks so far described are all of foreign design and represent the progress so far made in the matter in Europe.

Since the revival of general interest in floating docks in the United States further progress in the matter has been made in this country. The progress is based upon experience with the Clark dock and study of all existing and proposed types.

On Diagram 8 is shown a modified bolted sectional dock proposed by myself about three years ago. Figure 1 is a side elevation of a dock begun with three sections and later extended to five (two new ones dotted). Figure 2 is a side view showing the method of self-docking. Figures 3 and 4 are details showing different manners of connecting the sections. Figure 5 is an end view showing the lines and extent of connections. Figure 6 is a detail showing the connection of the pumping main between sections. In this type each section is a complete and independent dock in itself, and all sections are alike. The dock has the same advantage as the Rennie dock in that the pontoons can be built and launched separately, the side walls erected on them after they are afloat, and the sections finally assembled and connected. When connected up the entire dock can be operated from the pumping plant on one section. The possibilities of extension or separation into groups with this dock are of considerable importance commercially. The self-docking is simple and requires no special instruction or technical knowledge.

A disadvantage of the dock is that the pumping must be regulated from as many stations as there are sections. The repetition of sections does not give as great economy in disposition and location of material as is possible in a solid dock, but this is largely offset by the duplication of parts and labor, which simplifies and hastens the construction.

[1] Since the writing of this paper it has been learned that there is a land dock at Pola which will take the sections of this floating dock, and there is no intention of self-docking this particular dock.

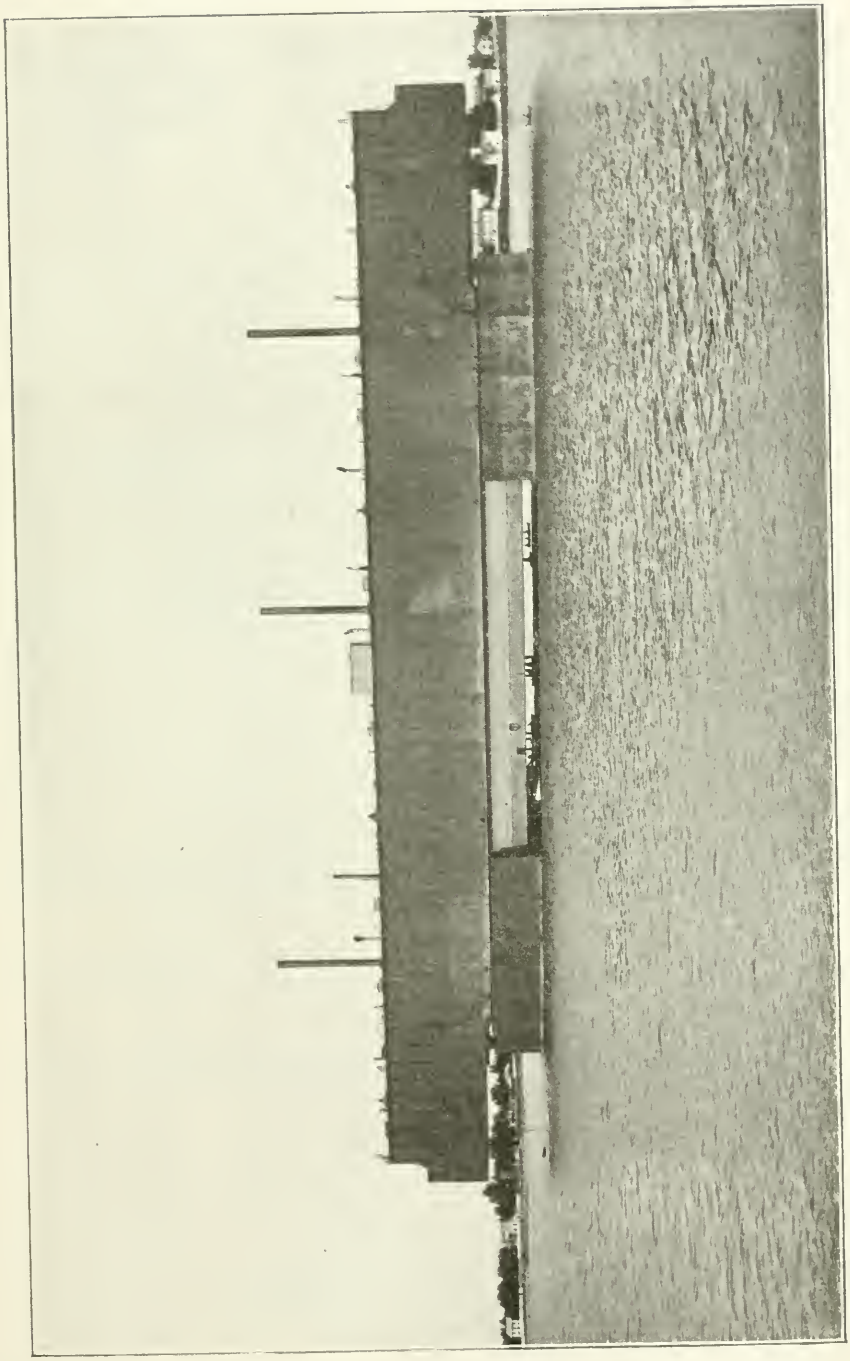


PLATE 2.—U. S. FLOATING DOCK "DEWEY," WITH CENTRAL PONTOON SELF-DOCKED ON THE END PONTOONS

The last floating dock design that has been produced is that of the Maryland Steel Company, by Mr. Henrik Hansson, one of the assistant engineers. This design was produced to meet the rigid and extensive requirements of the Bureau of Yards and Docks' specification for the government dock in the Philippines, the most exacting specification for floating docks that has so far been issued. The design was accepted and the dock built by the Maryland Steel Company.

The dock is illustrated on Diagram 9. Figure 1 is a side elevation. Figure 2 is an end elevation. Figure 3 is a plan. Figure 4 is a side elevation of the middle section self-docked. Figure 5 is an end elevation of the middle section self-docked. Figure 6 is a plan of the end sections self-docked. Figure 7 is an end elevation of an end section self-docked.

In the Maryland Steel Company dock great continuity has been secured. The side walls are continuous, and the long central pontoon is built solidly into them. The only break is in the short end pontoons, which form about one-fifth of the floor at each end, and the connections of these to the side walls and main pontoon are extensive and rigid. The low side walls on the end pontoons come into action only in self-docking, being ordinarily allowed to fill with water, and are again emptied automatically as the dock sinks and rises. These low side walls contain a pumping plant of sufficient capacity to operate the end pontoon, which is supplied with steam from a main boiler by a flexible connection. Ordinarily the small pumping plant in the low side wall is inoperative, the piping system of the end pontoon being connected to the main drainage system by a joint like that previously shown with the Cunningham dock.

In operation this dock has proved very rigid and reliable and easily operated. The self-docking has proven to be the easiest, simplest, and most quickly accomplished of any yet tried.

After this dock passes a certain length the width must also be increased in order to allow the end pontoons to be docked on the main portion.

In designing a floating dry dock the first matters receiving consideration are the clear width between side walls, the draught over keel blocks, and the length. For a commercial dock the maximum ship entering the port does not receive consideration, but rather a ship somewhat above the average, as it is the average ship that brings the largest and most profitable business to the dock. Ships below the

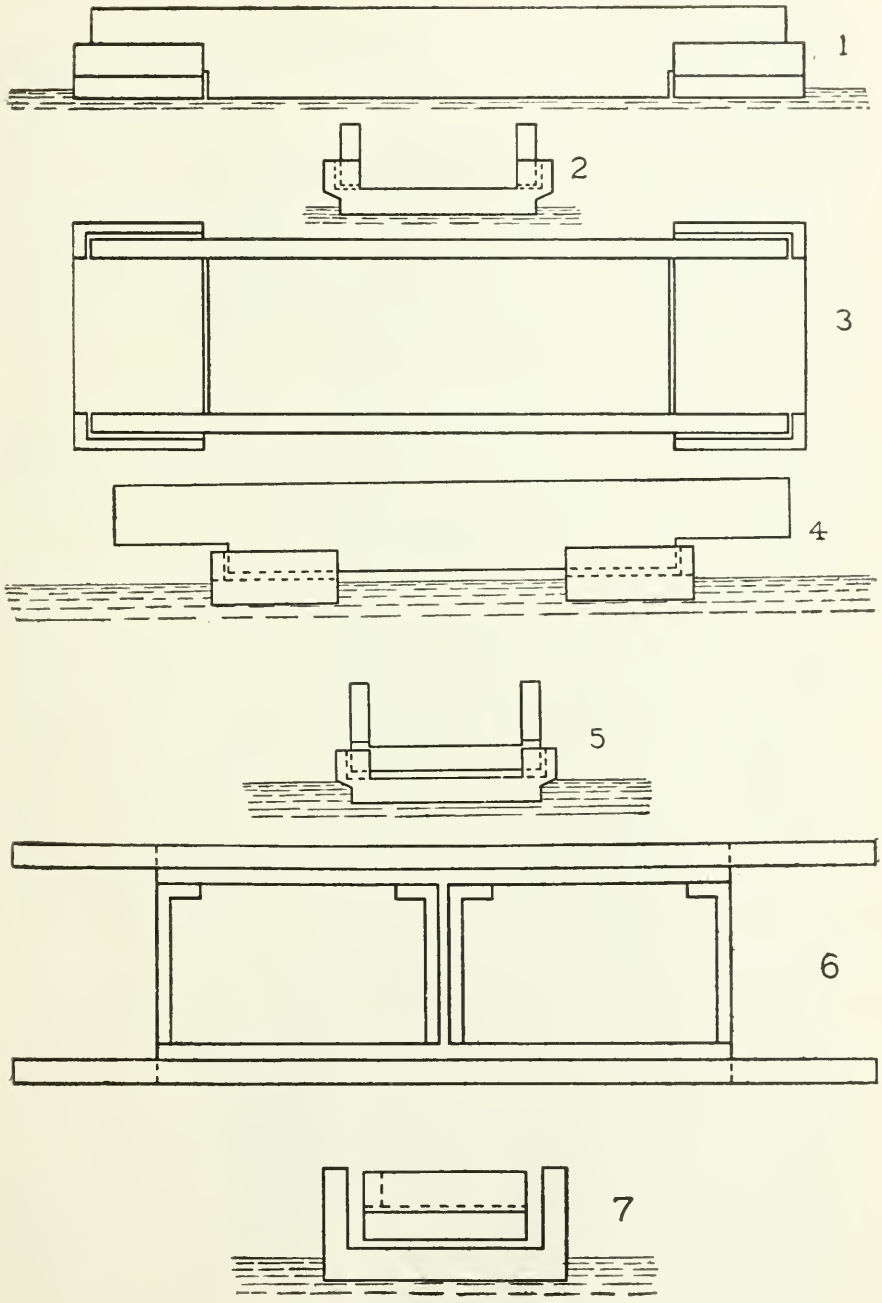


DIAGRAM 9. — THE "DEWEY"

average are, of course, readily handled by the dock, but the nearer it is worked up to its full capacity the greater will be the profit in the investment.

The determination of what will be the average ship during the life of the dock is a matter which requires careful consideration and study. Ships prefer to visit ports where there are docking facilities, and a large dock may invite larger ships than before cared to come. In any event, a large dock gives a port a favorable name among shipping interests. The coming growth in the size of ships in the future cannot always be predicted by the past, and as a general rule it may be said that it is more often the case that docks are designed too small rather than too large.

With military docks the case is somewhat different. Both the heaviest and longest vessels of a navy must be docked, and the heaviest and longest vessels likely to be built within a certain period are more easily predicted. At the same time liberal estimates should be the rule, for one warship that cannot be docked at home may place a navy in a serious predicament.

The clear width between side walls of a floating dock is not difficult to decide upon. It so happens that structural reasons have limited the maximum width of entrances to land dry docks throughout the world to 80 feet, and so by taking this dimension any ship now existing can be got into a floating dock, and for the average widths there will be a fair clearance for working space. This width is also desirable for general lateral stability of the dock. In the case of the United States government floating dry docks, the standard clear width between side walls is 100 feet. It is interesting to note that the maximum width of dry dock entrances throughout the world is one of the limiting factors of ship development.

The draught of water over the keel blocks must, of course, accommodate the normal draught of the maximum ship for which the dock is designed. In addition to this, provision should also be made for abnormal draught due to accident, and as a rule it is a wise proceeding to provide for the greatest draught of ship that is likely to be able to enter the port during the life of the dock. In military docks a deep draught over the keel blocks is of especial importance, as these docks are more likely than others to be called upon to handle disabled ships at an abnormal draught.

The length of a dock and its lifting capacity are two functions so

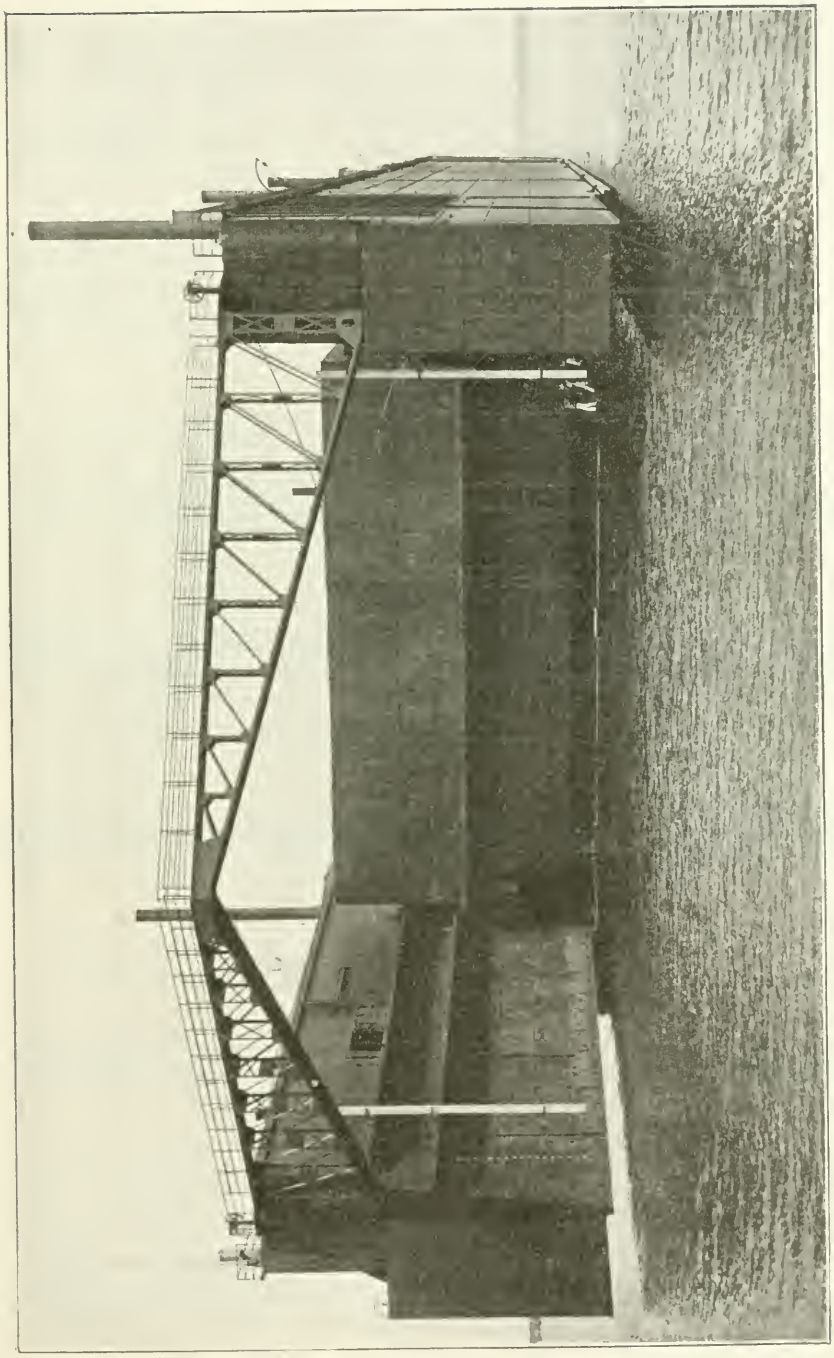


PLATE 3. — U. S. FLOATING DOCK "DEWEY," WITH END PONTOONS SELF-DOCKED ON THE CENTRAL PONTOON

closely related that they are best treated together, and the matter is most comprehensively considered in the case of a military dock. The military dock is called upon to deal with short battleships, long cruisers, and perhaps, in times of war, with still longer merchant ships that have been converted into naval auxiliaries. Full bearing length must

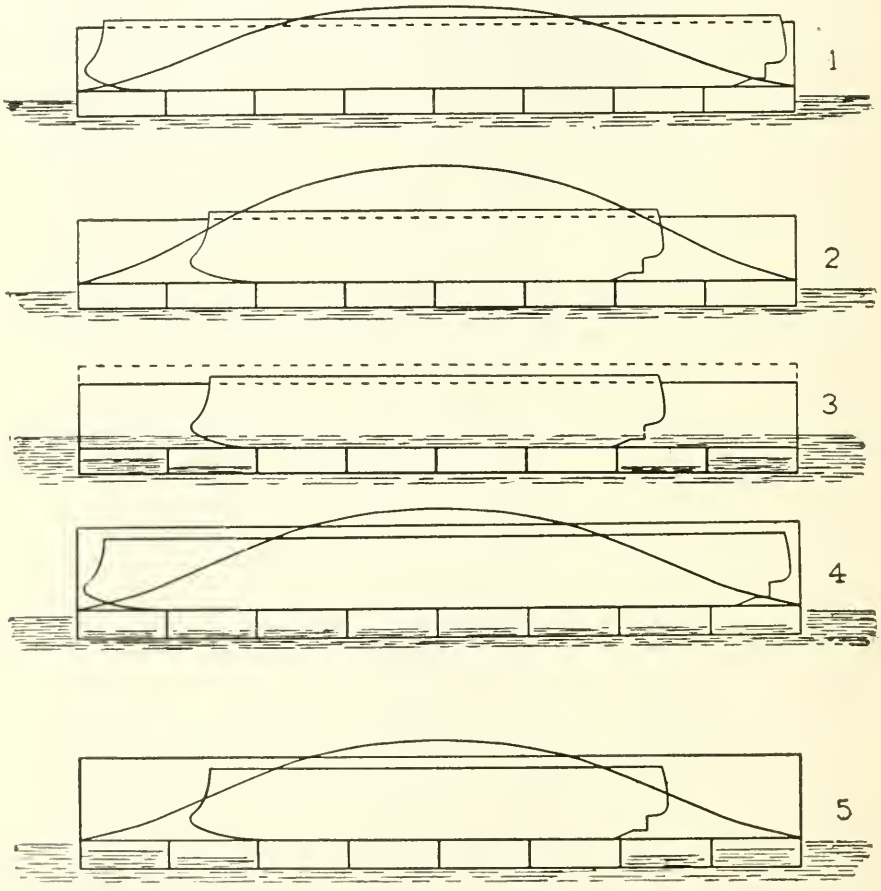


Diagram 10. — Curves of Bending Strain

be provided for the longest ship, and in addition a working platform is desirable under the ends of the ship that do not require bearing. This bearing length and working platform consist of the pontoons of the dock which give the lifting power, and there is a natural desire to utilize, so far as may be safely done, their entire displacement for lifting purposes.

The conditions to be met in the question of the length and lifting power of a floating dock are illustrated on Diagram 10, in which it is to be understood that the figures are diagrammatic only and for the purpose of illustration. In Figures 1 and 2 the docks are identical and the ships of the same weight, but of different bearing lengths. The dock has been designed just to lift the longer ship with all pontoons pumped empty. The bending strains for which the dock is designed under these conditions are the ordinates of the curve. Now to lift the short ship the pontoons must again all be pumped empty, but the upward leverage of the pontoons which are unopposed by the ship will greatly increase the bending stress and cause the curve to rise, perhaps to a point indicating danger or failure of material. The bending strains may be reduced by leaving water in the end pontoons, as in Figure 3, but under the conditions assumed the ship will not then come entirely out of the water. If the docks in Figures 1 and 2 are to have the same lifting capacity and are to lift both the long and short ships, there remains but one thing to do, and that is to increase the girder strength by raising the side walls, as shown by the dotted lines in Figure 3. In actual practice a compromise will give the best results, the side walls being raised somewhat to increase the girder strength and the pontoons deepened to give some excess of lifting capacity. In this compromise the condition of pumping and flotation are shown in Figures 4 and 5, and the bending strains are practically the same in both cases. This compromise necessitates skillful and intelligent pumping with short, heavy ships until the weight of the ship becomes less than the lifting capacity of the pontoons directly under it, after which pumping may proceed uniformly all over the dock without danger.

The United States government has been the first to refuse this compromise in the military dock for the Philippines, previously described. In that dock uniform pumping without undue strain is required for any load that it is possible for the dock to take. This would not be an economical requirement for a commercial dock, but in a military dock it insures many desirable qualities. It permits the most rapid lifting under all possible conditions. It is a safeguard against all careless and ignorant pumping which might be possible in emergency conditions. It makes it possible to hog or sag a ship on the dock for special repairs. It makes it possible to dock a ship near the end of the dock and also to dock it on an incline.

The general stability of a floating dock varies directly as the square

of the number of water-tight divisions. This is illustrated in Diagram 11. Figures 1 and 2 are cross sections of pontoons, having two and four water-tight compartments, respectively. The comparative stability of these as affected by the shifting of water ballast due to heeling is four to sixteen. The desirable longitudinal girders in a floating dry dock, shown in Figure 3, make six lateral compartments possible in connection with the structural design, so that in practice the shifting of water ballast from heeling is quite small.

The stability of a dock under various conditions in lifting a ship and in self-docking its own parts is an important matter. In the lifting of

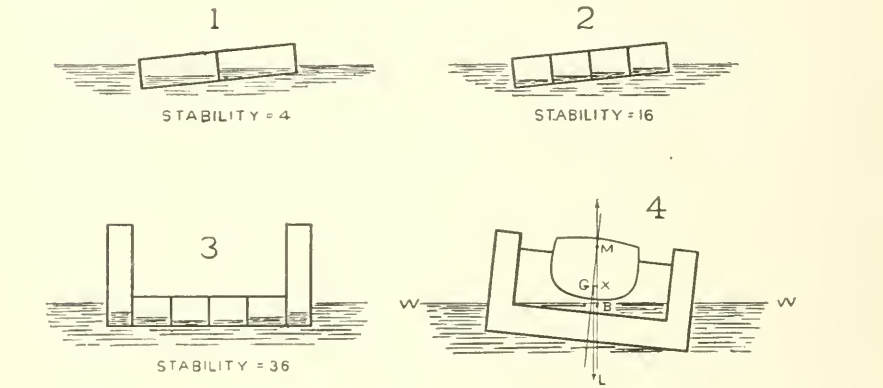


Diagram 11.—Correlation between Stability and Number of Water-tight Divisions

a ship the case is shown in Diagram 11, Figure 4. In this figure it is apparent, and it is confirmed by calculation, that the stability is the least with the water plane between the bottom of the ship's keel and the deck of the pontoons, for in this position the ship's buoyancy has entirely left the combination, the buoyancy of the pontoons themselves has not yet come into play, and the comparatively slight buoyancy of the side walls is all there is to resist overturning. The stability of the combined ship and dock at this particular period may be largely controlled by the pumping in a dock where but little shifting of water ballast is possible, for the more nearly the dock is kept level the greater the metacentric height. With a well-designed floating dock it is an

easy matter so to conduct the pumping that the dock will never be more than from 6 inches to 1 foot out of level, and under no circumstances is it necessary that the dock should be more than 2 feet out of level in raising a ship. Two feet out of level, however, is only about 1° with a fair-sized dock, and may be taken for the possible list in considering stability. Using 1° as the possible list of the dock after the ship is entirely out of the water and before the pontoon decks have come above the surface of the water in sufficiently numerous calculations has shown that the metacentric height for this position of least stability will vary from 5 feet to 20 feet, according to the cross section of the combination of ship and dock. In comparison with the metacentric height of a ship that may be from 1 to 3 feet with the same degree of heel, the great stability of a floating dock under the worst condition is at once apparent. The stability of a floating dock of approximately standard cross section and design is so well assured that the calculations are more a matter of interest than necessity.

Apparently the most unstable position of self-docking shown in the preceding diagrams is that of the main portion of the Maryland Steel Company dock; but even in this at the plane of least stability the metacentric height is 17.82 feet.

The next matter for consideration is the deflection of a floating dry dock under the various loads and conditions. The longitudinal deflection under the maximum loads is a matter which gives more concern to designers than any other consideration. It is the governing factor in the relation of length to total lifting power, height of side walls, and total amount of material entering into the structure. The earlier floating docks had to deal with comparatively short ships of considerable inherent stiffness, but the modern floating dock, and especially the military dock, has to deal with ships both long and short, having great weight unevenly distributed and considerable flexibility when not water borne. Some designers have prided themselves on the small weight of their docks compared to the total lifting power, frequently getting the structural weight of the dock less than 40 per cent. of its total displacement capacity. Such docks will always give a large deflection, and as they deteriorate from age may become a menace to themselves and the ship they carry when worked up to their apparent capacity.

Under the possible load which a dock can lift, which is determined by its displacement, there is certain to be deflection, as the dock is

built of elastic material and supported by a liquid medium. This greatest possible deflection should be confined within safe limits, both for the ship and dock.

Having determined and limited the greatest possible deflection, the deflections of the dock at its rated capacity must be established.

Until recent years dock designers have been largely satisfied with safely lifting a ship and returning it to the water uninjured, and as long as this was the ruling condition there could be no marked advance in floating docks.

The United States government, in its new floating dock for the Philippines, has inaugurated a new deflection requirement that marks a decided and important advance in this line.

The deflection of the dock is limited to a small amount under the full rated capacity, with the dock pumped uniformly all over.

The full effect of limited deflection under uniform pumping is best shown by a comparison. In the government dock at New Orleans uniform pumping was not specified; the dock is 525 feet long, has a rated capacity of 15,000 tons, a displacement of 18,000 tons, and a total weight of about 6,000 tons. The new Philippine dock, in which uniform pumping was specified, is 500 feet long, has a rated capacity of 16,000 tons, a displacement of 22,000 tons, and a total weight of about 11,000 tons; when pumped in the manner allowed for the New Orleans dock it will dock a 20,000 ton battleship with only slight deflection. (Limiting the deflection under uniform pumping has, therefore, about doubled the strength of the Philippine dock as compared with the New Orleans dock.)

Some of the reasons for uniform pumping in a military dock have already been given. Other reasons are that a dock so designed can be water ballasted until the deflection under the rated load is all removed and the ship brought to a straight keel or even hogged. Repairs and changes can then be made under the same conditions as when a ship was built, the structural advantages of which are great.

This liberality of design which is desirable in a military dock may not always be expedient in a commercial dock, but in any event the deflection should be kept within the safe limits of the elasticity of any hull which it is possible for the dock to lift.

On account of the shorter span and the necessary uniform pumping athwartship, the transverse deflections in a dock are more easily dealt with, but they should always be calculated and limited without esti-

mating on the use of shores from the side walls of the dock to the ship.

The dimensions and capacity of a floating dry dock having been determined and its structural strength decided, there remains to be selected the method of self-docking that will best suit these conditions.

The preservation of a large floating dry dock is of so much importance that there is sometimes a tendency to give the self-docking feature an ascendency over the regular functions and purposes of the dock.

In general, the following principles should govern the self-docking features of a floating dry dock: Great continuity in docking operations; smallest possible number of divisions and auxiliaries; joints at greatest possible distances from points of greatest strain; joints always dry and accessible; simple and easily understood method; remoteness or impossibility of accident in self-docking; largest possible stability and strength when self-docked; quickness of self-docking and reassembling.

Diagram 12. — Docks with Caisson

Many of these desirable features are antagonistic, and how well they have been met, coördinated, and reconciled up to the present time can be seen by a study and comparison of the types previously presented. These types, it is believed, represent the best of every class that has been devised, and under them there are many unimportant and mostly valueless variations.

The quickness of self-docking is a most important matter in any dock, but especially so in a busy and prosperous commercial dock. If self-docking is long, complicated, or liable to give trouble, it will never be attempted until absolutely necessary, and in the meantime the under-water portion of the dock structure may have suffered much deterioration.

The best record yet made in self-docking is that of the new government dry dock for the Philippines, which was self-docked and reassembled on the first trial in fourteen days. It is believed that on a subsequent trial this time could be reduced to ten days.

This does not take into account any extensive cleaning or painting that might be desirable, and to completely clean and paint the submerged portions of an extensive floating dock would, under the most favorable conditions, require from one to three months.

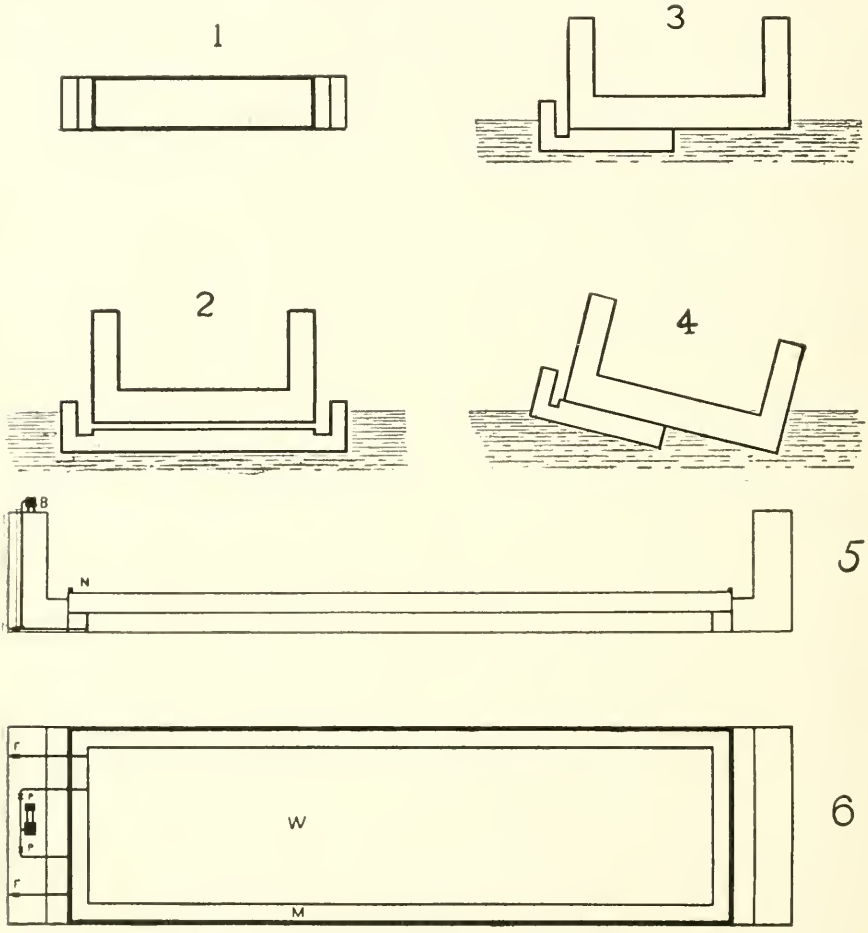


DIAGRAM 13. — THE NEW CUNNINGHAM CAISSON
B, pump; *F*, flushing valve; *M*, flotation chamber; *N*, packing ring; *P*, pump valves; *W*, working chamber

The more experience that is gained with self-docking docks, the more desirable does a return to the original solid type appear. To this end an adaptation of the ship caisson has been proposed in this country, and is understood to have been tried unsuccessfully in Europe. The application is illustrated in Diagram 12. Figure 1 is an end view of a

dock with a caisson extending entirely across the bottom and up both sides above the water line. Figure 2 is an end view of a dock with a caisson extending just past the centre and up one side. These caissons are entirely open on the sides next the dock. The proposition is to make them water-tight against the dock, and then pump out the contained water, so that the submerged portions of the dock will become accessible. The difficulties to be encountered with these caissons are evident. In Figure 1 it would be a mechanical impossibility to make a water-tight joint on both sides at once, and the sag would leave more or less opening at the bottom. In Figure 2 there would be much difficulty in controlling the caisson, and the end under the dock could not be got up sufficiently tight against the dock to make pumping effective. I have recently proposed a caisson, which is here generally announced for the first time, which has worked satisfactorily in a scale model and which may possibly solve this problem. The caisson is illustrated in Diagram 13. Figure 1 is a plan of the caisson. Figure 2 is an end view of a dock with a caisson extending entirely across before lifting against the bottom. Figure 3 is an end view of a dock with a short caisson sealed against the bottom. Figure 5 is a sectional elevation, and Figure 6 a sectional plan of the caisson, showing the general arrangement.

The action of this caisson is as follows: Water is admitted to the main chamber freely until the combination is sunk as far as the displacement of the supplemental chamber will permit, which is less than submergence. Water is then carefully admitted to the supplemental chamber until the combination just loses its buoyancy. The caisson then sinks until arrested by the floats attached to the entrance shafts, and is then ready to move into position under the dock. In the case of the short caisson an approximate level is maintained by counterbalancing the caisson chamber. Being in the desired position, the water is exhausted from the supplemental chamber and the caisson rises and seals against the bottom of the dock, after which the main chamber can be pumped dry, giving access to the bottom of the dock. The manner of gaining access to the edges of the dock is shown in Figure 4. The caisson is sealed against the bottom of the dock, with the end projecting; the edge of the dock and the projecting end of the caisson are then canted out of water, after which the main caisson chamber can be pumped dry.

The successful application of the caisson to the bottom of a floating

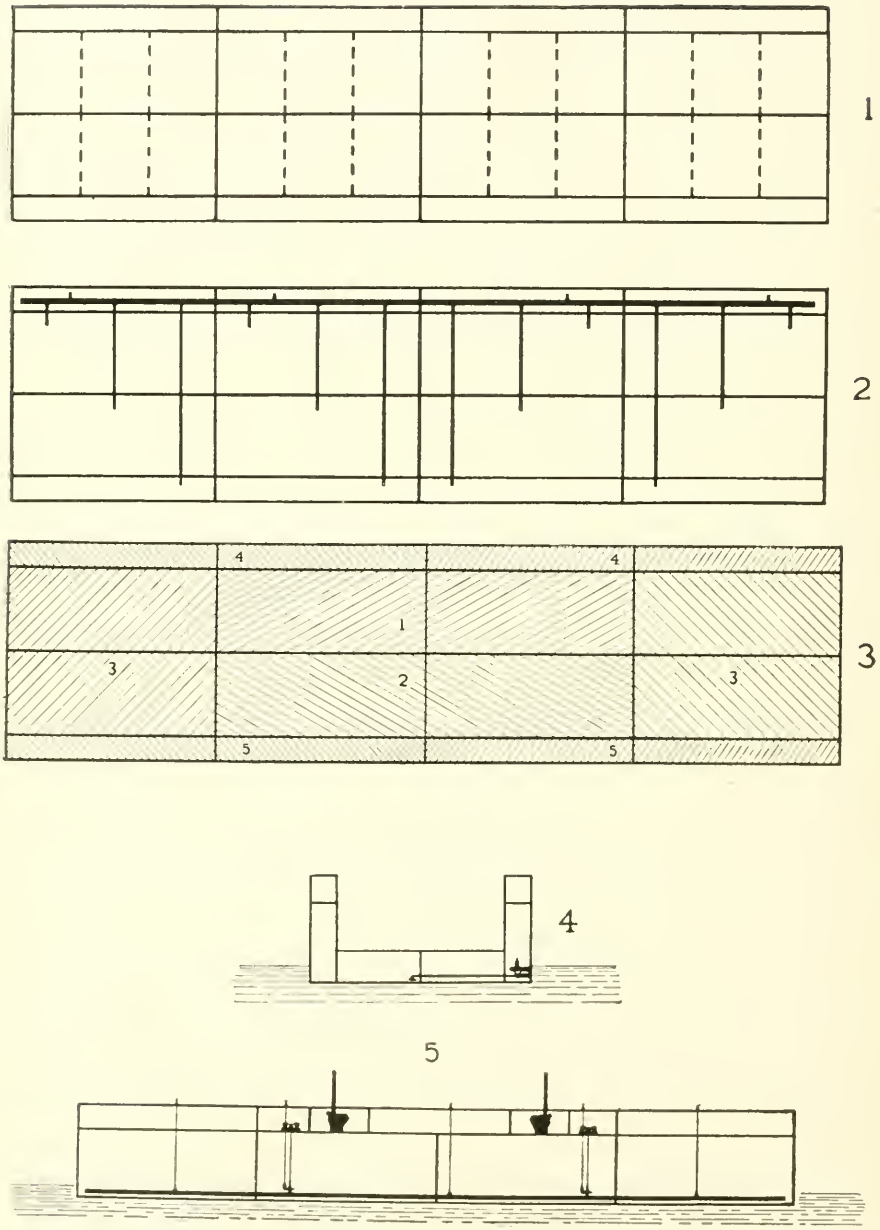


Diagram 14.—General Principles of Floating Dry Dock Construction

dry dock will permit a return to the solid type to which all self-docking docks strive to approximate. It will further permit of the painting or repair of the bottom of the dock at the same time that a ship is undergoing repairs in the dock; and the only time that the dock cannot be in use is when working on the edges. In the solid dock the construction will not only be strengthened and simplified, but the pumping system as well will be much more simple and easily arranged.

The general principles on which all floating dry docks are constructed are illustrated in Diagram 14. Figure 1 is a plan view of the pontoon or body of the dock, with the lines of girders. The solid lines are water-tight bulkheads, and the dotted lines are open bulkheads, or trusses. Figure 2 is a plan view showing the water-tight compartments alone and the piping leading into them from the pumping main in the side wall. There may be a pumping main in each side wall, but it is considered better practice to have it only on one side, as the pumping is then more directly under the observation and control of the dock master. Each pipe is controlled by a quick-acting wedge valve. For the easier regulation of the pumping, the balancing of the dock, and the application of the lifting power in the correct manner the water-tight compartments are collected into groups, as shown in Plan 3. The valves of all the pipes leading into a group are coupled to one valve rod, so that all are opened or shut together. All the valve rods are brought to one station by a system of bell crank levers, and at this station the dock master regulates the entire pumping of the dock. Figure 4 is an end elevation of the dock, showing the longitudinal lines of water-tight bulkheads. The pumping main, with pump located on top, and discharge outboard are shown, and also the flooding inlets and the lead of a pipe to a compartment.

Figure 5 is a side elevation of the dock, showing the framing and bulkheads in the side walls, the engine deck with engines and boilers, and the pumping main with its pumps and flooding inlets. Three pumping units are the least that should be installed on a large floating dock in order to secure a fairly uniform flow of water from all compartments and to provide against serious disablement in case of any breakdown. (In the case of a commercial dock whose location is fixed, the pumps may be operated to advantage by motors supplied with power from a station on shore.)

In docking a ship the following method of pumping will always be correct, whether the dock is designed for uniform pumping or not. The ship having been centred, pump uniformly until the ship is seated

firmly, it making little difference whether the blocks are taken at the bow or stern first; if there is any preference it is usually the bow. After the ship is seated pump from the centre of the dock first, gradually extending the pumping towards the ends in the order indicated by the numbers in Figure 3, Diagram 14. The pumping of the side walls is held back to secure quick balancing, and incidentally for priming the pumps if the pumping is temporarily stopped towards the last stages. Only slight regulation of valves is necessary to keep the dock level

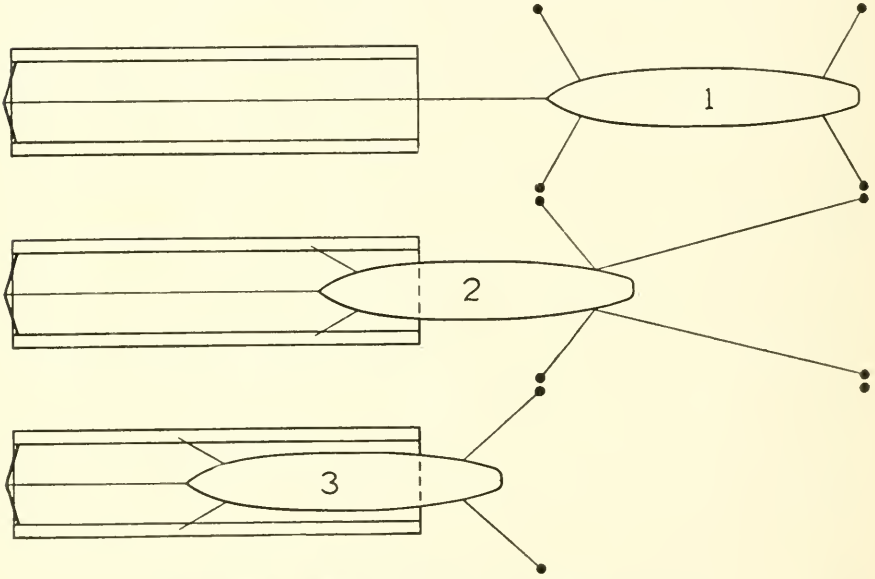


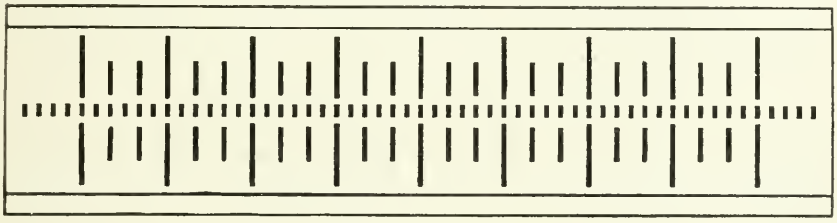
Diagram 15.—Method of Placing a Ship in Dock

where the arrangement of groups is correct and where there is an ample flow of water through the pipes.

The side wall decks of a dock should be fully equipped with capstans, fairleads, and bitts. A bridge at the forward end for a headline is desirable, but not absolutely necessary. With four moorings at the entrance of a dock, it is entirely possible to take a ship in without the use of tugs. On Diagram 15 is shown the placing of a ship in dock. Figure 1 is the ship held by the buoys and with a headline out. Figure 2 shows the ship about one-third entered and the lead of the lines at that time. Figure 3 shows the ship three-quarters entered and the lead of the lines. Leaving the dock is easier than entering it, for as soon as the ship's stern is clear she may be started astern and clear the dock very quickly.

The government requires that the pontoon decks of its docks shall be made sufficiently strong to take blocking at any point; so far this has not been generally the case with commercial docks, but it is a valuable property and deserving of consideration for all docks. The arrangement of blocking on a government dock is shown on Diagram 16. Figure 1 is a plan and Figure 2 an end elevation. Shores may also be used from the stages on the side walls.

The limited width of the entrances to land dry docks and its effect on the development of ships have been referred to. The depth of water over the sill of land dry docks is another limiting factor of ship development; and when it is considered that from five to eight years are



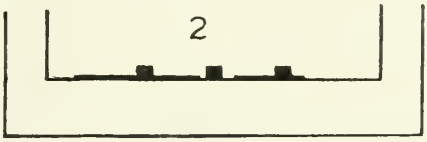


Diagram 16. — Arrangement of Blocking on a Government Dock

required for the construction of a land dry dock, it would seem as if any general increase in the size of ships had nearly reached the limit at the present time. Should any radical development in ship design be determined on, the immediate relief will be found in the floating dock, for it can be constructed of any dimensions and capacity desired in less time than a ship can be built, and it can be towed to any location desired.

The extent of this paper only permits of the treatment of the most general and important principles of floating dry docks. While the details are both important and interesting, a general and comprehensive understanding of the subject is the best foundation for those who desire to go farther into the question.

Contribution from the Sanitary Research Laboratory and Sewage Experiment Station of the Massachusetts Institute of Technology

THE STERILIZATION OF SEWAGE-FILTER EFFLUENTS

By EARLE B. PHELPS and WILLIAM T. CARPENTER

The Desirability of Sterilization

The primary purpose of sewage purification is the protection of the purity of the streams. The Lawrence experiments first showed that, by means of sand filters, sewage could be purified to an extent which is for all practical purposes complete. This means that practically all the organic matter and the living bacteria of the sewage are either removed or converted into harmless mineral constituents. Such a degree of purification is possible, but it involves the use of such large areas of suitable sandy land that, except under the most favorable circumstances, its cost to a city of moderate size is practically prohibitive. Consequently the tendency for the past decade has been toward more rapid processes of purification; that is, processes requiring smaller areas of land for the treatment of given volumes of sewage. The results of experiments along this line, carried on in many parts of the world, are now well known. We have seen the successive development of the septic tank, the contact filter, and the trickling filter, each of which has resulted in an increase in the possible rate of treatment, until the original maximum rate of fifty or sixty thousand gallons per acre per day has been multiplied fifty fold or more. This great saving in filter area has not been obtained without some sacrifice. With the progressive increase in the rate of treatment there has come a more or less progressive deterioration in the quality of the effluent, so that the effluent of a modern trickling filter, so far as appearance goes, and indeed often in its chemical analysis, seems to be little better than the crude

sewage. But there is one essential difference. In passing through the filter the sewage has been robbed of its putrescibility, that is, of its tendency to undergo offensive putrefactive fermentation. The organic matter of the sewage is unstable, or liable to putrefy, while that of the effluent is stable. And we have learned that in bringing about this one change in the character of the organic matter we have accomplished the most essential thing in sewage purification, as will be seen if we analyze a little more in detail the effects of stream pollution. These may be conveniently considered under three heads — æsthetic, economic, and sanitary.

The discharge of a relatively small amount of sewage into a stream brings about no serious physical conditions. As the amount of sewage increases year by year, however, there is ever increasing evidence of its presence. The waters become discolored, a greasy scum appears on the surface, and, worst of all, the black mud deposited upon the bottom ferments, giving rise to malodorous gases. Finally, if the sewage be added in still greater amounts a point is reached, quite suddenly, at which the balance swings, and the stream becomes permanently black and offensive and will no longer support fish or other life. It has, in fact, changed from a polluted river to a sewer. There may be no thought of using this stream for domestic purposes, and there may even be no serious monetary damage involved, but there can be no more potent argument for sewage purification than such a ceaseless offence to the eyes and nostrils of the community. It is now a recognized fact that to prevent such conditions as these it is not necessary to free an effluent from organic matter, much less from bacteria, but that it is alone sufficient to render it thoroughly stable.

There are also certain definite economic damages caused by stream pollution. Communities are ofttimes under the necessity of using for sources of domestic water supply the waters of polluted streams. Still more frequently such sources are much more available than a more distant unpolluted source, and it is found to be more economical to filter the polluted water than to bring in the more distant one. No contention can be made that streams should be so far protected that they may be used directly for public water supplies. In the very nature of the case, streams flowing through populated regions are polluted, and the complete purification of the cities' sewage would still leave countless small but significant sources of possible infection. Therefore, the contention that it is not the duty of the sewage works

to turn out a potable water seems reasonable. All ends are served most fairly and most economically by placing upon the water filter the burden of producing an unpolluted water for domestic use. It must be obvious, however, that the condition of gross physical nuisance described above as an open sewer rather than a polluted river must render it impractical, if not impossible, to treat such a water upon a water filter in the ordinary manner. It is equally true, though less obvious, that any considerable pollution of a stream by putrescible organic matter increases the work of the water filter and, in consequence, reduces its factor of safety and efficiency in the removal of disease germs. This contention will become more obvious if we bear in mind the fact that putrescible organic matter is matter requiring oxygen to render it stable, and that the work of the water filter is simply the oxidation of all such matter, together with the organic matter of the living bacteria and other organized animal and vegetable forms. To offset, therefore, this increased pollution lower rates of filtration and larger areas are necessary, with consequent increased expense for construction and maintenance.

Among other financial losses it is sufficient to mention the harm done to profitable fishing, decreased value of the water for industrial purposes, depreciated land values, and other monetary losses due to causes described as æsthetic.

In any equitable solution of the problem we must seek the middle ground, and carefully balance the cost of purifying sewage to any given degree of purity against the saving in filter area and maintenance thereby made possible on the water plant, and against other economic advantages. Experience has shown that non-putrescible effluents can be obtained from sewage filters run at feasible rates, and that the discharge of such effluents, if reasonably free from suspended matter, will throw little or no additional burden upon the water filter; that raw sewage or putrescible effluents reduce the power of the stream to maintain its own normal character and render its subsequent purification more difficult; and that the benefits of any more complete purification of the sewage beyond the point of perfect stability will be entirely incommensurate with their cost. Therefore the economic as well as the æsthetic arguments for the purification of sewage are met by such a treatment as will produce non-putrefactive effluents.

Sanitary considerations are themselves economic in their ultimate

analyses, but there are certain aspects of the present subject which are, primarily, sanitary. The relation of sewage disposal to water filtration has already been commented upon. In the discussion of the economic phase of this relation it was assumed that satisfactory purification of the water would be obtained at whatever cost. Where polluted waters are being taken directly into the city mains the question is naturally a serious sanitary one, but again it must be asserted that the responsibility rests upon that community using the water. The most efficient purification of the sewage before discharge will never make a water safe which drains a populated country. The sewage can and should be rendered non-putrescible, but it will still be germ-laden. The removal of these residual germs, together with those others which by scores of devious and hidden paths have found their way into the stream, must depend upon the water works authorities. The case is aptly put by that dictum ascribed to Mr. Hering: "Nothing to be discharged into a stream without purification; nothing to be taken from a stream without purification." The greatest good to the greatest number finds its solution in this system of dual responsibility.

Sewage disposal has, therefore, curiously enough come to be less and less a matter of sanitation. As the practice has gradually developed from the slow sand filter toward rapid, coarse-grained filters, it has become more obvious that the removal of bacteria is not one of the functions of a sewage filter. There is, as a rule, a removal of a portion of these organisms. Whether or not there is a satisfactory elimination of the dangerous germs of disease is a point upon which there is great diversity of opinion and very little exact knowledge.

It was seriously feared at one time that pathogenic germs might multiply in the septic tank. Woodhead made physiological tests of crude sewage and septic tank effluent, and concluded that there were no organisms in the latter capable of setting up morbid changes in animals after inoculation. Rideal states that "satisfactory evidence in most of the systems is now available, from which I think we are justified in concluding that, even if towns on a river like the Thames adopted bacterial schemes, the pathogenicity of the London water supply would not be adversely affected." (Great Britain, 1902, A, Quest. 4148.)

On the other hand, Houston, acting for the Royal Sewage Commission, made a careful bacteriological study of the whole problem. He concludes that:

The effluents from septic tanks, intermittent contact beds, continuous filtration beds, etc., contain an enormous number of bacteria. In some cases the percentage reduction of microbes in effluent as compared with raw sewage is striking; but as an effluent must be judged by the actual state it is in, and as the number of microörganisms still remaining is almost always very large, percentage purification would seem to be of minor importance. In not a few cases the bacteria are practically as numerous in the effluent as in the raw sewage.

The different kinds of bacteria and their relative abundance appear to be very much the same in the effluents as in the crude sewage. Thus, as regards undesirable bacteria, the effluents frequently contain nearly as many *B. coli*, proteus-like germs, spores of *B. enteritidis sporogenes* and streptococci, as crude sewage. In no case, seemingly, has the reduction of these objectionable bacteria been so marked as to be very material from the point of view of the epidemiologist. No definite proof has been furnished that the effluents from bacteria beds are conspicuously more safe in this sense in their possible relation to disease than is crude sewage. Indeed, all the available evidence tends to show that they must be regarded as nearly if not quite as dangerous to health as raw sewage. In this connection we would again take note of the streptococcus test. If it be true that streptococci are more delicate germs than the typhoid bacillus, their presence in any number in the effluent would seem to indicate the possibility or probability of the enteric fever bacillus also surviving under similar conditions, and, in general, would lead us to infer that the biological processes at work were not strongly inimical, if hostile at all, to the vitality of germs of pathogenic sort. (Great Britain, 1902, B, p. 26.)

At the Sewage Experiment Station of the Massachusetts Institute of Technology, bacteriological examination of crude sewage and of the effluents of four septic tanks and fifteen filters were made during the summer season. The following average results were reported by Winslow (1904):

Sample.	Number of Examinations.	Bacteria per Cubic Centimeter.					
		Lactose gelatin at 20° C.			Lactose agar at 37° C.		Anaërobic agar.
		Liquefiers.	Acid formers.	Total.	Acid formers.	Total.	
Sewage	56	365,000	1,670,000	5,430,000	1,670,000	3,760,000	2,440,000
Septic effluent . . .	56	162,000	495,000	1,750,000	650,000	1,040,000	930,000
Contact filters . . .	140	60,000	270,000	1,060,000	290,000	570,000	440,000
Trickling filters . .	18	134,000	114,000	451,000	284,000	1,170,000	200,000
Sand filters	15	500	1,360	9,160	11,400	43,600	1,200

There were four septic tanks running at storage periods of from twelve to forty hours, nine contact filters differing in material, depth, and rate, three trickling filters, and three sand filters, each set running with crude and two kinds of septic sewage.

The septic tank and two trickling filters now in operation at this station gave the following bacterial results, the figures being averages of the results of almost daily examination during the past summer.

	Bacteria per c.c. Lactose agar at 37°.	B. coli. Positive * tests in $\frac{1}{100000}$ c.c.
Sewage	1,300,000	65 per cent.
Trickling filter receiving sewage	750,000	35 per cent.
Septic effluent	1,650,000	66 per cent.
Trickling filter receiving septic effluent	750,000	35 per cent.

* The bile broth presumptive test, recommended by Jackson (1906), was employed.

About one-half the total organisms were removed by filtration, and the reduction of *B. coli* was practically in the same proportion. Such results as these would seem to justify fully the statement quoted from Houston.

We are still ignorant of the fate of the dangerous pathogenic organisms, so far as any direct experimental knowledge goes. In the absence of such knowledge it is only reasonable and safe to assume that such organisms do, in part, at least, pass through the filter.

We must therefore conclude that sewage purification by modern processes can be made to produce effluents which are reasonably clear and stable, but which are still germ-laden and, potentially, infectious; that the discharge of such effluents into streams or tidal waters will not bring about physical nuisance or economic damage; and that, so far as the use of water for domestic and industrial purposes is concerned, such discharge is just and reasonable.

At the present time, however, we are confronted with a consideration which promises to add a new chapter to the history of sewage purification. This is the question of the relation of sewage pollution and sewage disposal to the shellfish industry. Many of the oyster and clam beds of our eastern seaboard are seriously polluted with sewage. Both at home and abroad this subject has reached the magnitude of a "scare," and a serious falling off in the demand for these shellfish is reported. In this country, at least, most of this pollution is due to

the discharge of untreated sewage into the rivers and tidal waters. In Great Britain it is more commonly the result of the discharge of partially purified effluents which are quite stable, as we have described them, but germ-laden. In many places the matter is being studied or agitated. In Great Britain the Royal Sewage Commission has issued a voluminous and valuable report upon the pollution of shellfish (Great Britain, 1904). In our own country the Massachusetts State Board of Health has had the question under investigation for several years, and has just issued a valuable report bearing upon the subject (Massachusetts, 1906); New York State has a Harbor Pollution Commission which for two years has studied conditions in New York Harbor; New Jersey is alive to the danger which threatens one of her great industries; and Baltimore is taking active steps to improve the sanitary conditions of upper Chesapeake Bay. The difficulties of the situation are obvious. A polluted river water may be rendered potable through filtration, but purification of shellfish seems to be out of the question. It follows, then, that the bacteria of sewage must not be discharged upon shellfish beds. The kind of purification which we have discussed will no longer serve, for sanitary considerations are here paramount. A higher standard of purity — a bacterial purity as well as an organic stability — must be demanded in such cases, or else the taking of shellfish must be prohibited. When the community is large and the shellfish industry small this latter alternative will probably prove the more satisfactory. Where small communities are polluting large and important beds, thorough purification by sand filters is not an unreasonable requirement. Unfortunately, the greatest shellfish areas of the country are so situated that they are subject directly or indirectly to possible pollution from concentrated populations.

In a carefully prepared paper on this subject by Mr. G. W. Fuller (1905) it is stated that the annual crop of oysters gathered along the Atlantic and Gulf coasts in 1902 amounted to over twenty-five million bushels, valued at over thirteen million dollars, and that the crop of clams was over two million bushels, valued at two million dollars. Over one-half of this total product came from the three states of New Jersey, Maryland, and Virginia, and were, in the main, grown in the waters of the Delaware and Chesapeake Bays, into which the sewage of Philadelphia, Wilmington, Baltimore, Washington, and other cities is discharged. At present, owing to the tremendous dilution of the polluting matters in these bays, the danger of pollution is

in most cases remote, but it is significant, ever present, and ever increasing. The great value of the industry and the even slight danger to which it is now exposed has called for action on the part of those most interested. In Baltimore a system of sewerage and sewage disposal is being planned by which it is intended to remedy the present serious pollution of the Patapsco. In calling upon a commission of experts for advice, the Sewerage Commission of Baltimore distinctly specified "that the effluent proposed to be discharged into Chesapeake Bay or its tributaries in the system to be recommended by the engineers shall be of the highest degree of purity." By a coöperative arrangement between the states of New Jersey and Pennsylvania the condition of the Delaware River is being investigated, and measures will be considered by which the present serious pollution of that river shall be remedied.

It seems that in such cases the value of the industry, together with the difficulty of protecting the beds in any other way, will ultimately force upon the authorities one of two alternatives: complete purification by filtration through sand, or rapid and partial purification by means of contact beds or trickling filters, followed by some kind of sterilization.

The former is practically what has been recommended for the city of Baltimore, although it is there proposed to make use of sand filtration as a secondary process, following treatment on trickling filters. In this way the efficiency of the sand filtration is obtained at a considerable saving in filtration area. The Board of Advisory Engineers has estimated the cost of works for the complete treatment of seventy-five million gallons of sewage per day at $3,283,250, of which sum $1,040,750, or over 31 per cent., is for the supplementary treatment on sand filters. The annual cost of operation is estimated at $115,500, of which $55,000, or 48 per cent., is for the supplementary treatment (Baltimore, 1906). This gives some idea of the price which it is necessary to pay for effluents of bacterial purity over and above the cost of rendering the sewage stable and non-putrefactive. In regard to sterilization by chemicals, the engineers report that "to remove all bacteria remaining in the settled effluent from the sprinkling filters by disinfectants, such as hypochlorite of lime or of sodium or sulphate of copper, would be prohibitively expensive"; and this opinion is based upon the best knowledge of the subject now available. The fact is, this alternative — chemical sterilization — has not yet

been reduced to its lowest terms. We have yet to learn how effective it may be made and at what cost, and what after effects, objectionable or otherwise, are likely to follow its employment.

A somewhat careful study of the question has forced the authors to the belief that there is much of value in this process, and that under certain circumstances and conditions which are common in this country, particularly where the oyster question is involved, it may be found to be the best possible solution of the whole problem.

In connection with an experimental study of certain kinds of chemical sterilization, the results of which are here presented, the literature of the subject has been thoroughly reviewed, and it is thought that a summary of our available information might prove of value. In connection with the experimental data which have been compiled, the all-important question of cost has been gone into in some detail, particularly in the case of those processes which in other respects appear to be feasible.

The Efficiency and Cost of Sterilization

In Great Britain the somewhat indefinite allusions of the Royal Sewage Commission to the question of sterilization as a finishing process in sewage treatment have aroused a storm of discussion and resulted, at least, in clearing away many misconceptions. Sterilization processes of many kinds have been investigated, and the subject has been freely discussed. For the following classification of sterilizing agents and for many of the facts here cited the writers are indebted to Rideal (1905), whose careful paper on the subject discusses its possibilities in a thoroughly impartial manner. Other authorities are cited so far as possible. Except when otherwise stated, costs are based upon present Boston prices.

The various methods proposed for the sterilization of effluents will be taken up in the following order.

1. Heat.
2. Lime.
3. Acids.
4. Ozone.
5. Chlorine and its compounds.
   - (*a*) Chlorine gas.
   - (*b*) Oxychlorides.
   - (*c*) Chloride of lime; hypochlorites.

6. Copper and its compounds.
7. Miscellaneous.
   (*a*) Permanganate.
   (*b*) "Amines."

1. Heat. — The use of heat has been suggested for the sterilization of sewage and effluents. In his testimony before the Royal Commission, Klein (Great Britain, 1902, A, Quest. 9674) referred to a patented apparatus which he considers quite feasible, and by the use of which enough ammonia was to be recovered nearly to pay for the fuel required. There is no record that this device has ever been used on a large scale, and its claims are almost too fanciful. A rough calculation of the anthracite coal necessary to raise sewage to the boiling point from the average temperature of 60° F. gives 40 tons per million gallons, which will cost say $4 per ton, or $160. The total amount of free ammonia in a million gallons of Boston sewage is about 100 pounds, which, if concentrated to the commercial strength of 28 per cent., would bring 40 cents per pound, or $40. These are the most favorable figures possible, and in reality the revenue would be a much smaller proportion of the cost. Sterilizing by heat, therefore, will be a very expensive process and may safely be disregarded.

2. Lime. — Caustic lime acts as a weak germicide. The considerable removal of bacteria noted when lime is used as a precipitant for sewage is undoubtedly due to the action of the precipitate itself in dragging down with it the bacteria which it has entangled. Such an action is common in all precipitation, and even the sedimentation of sewage is always accompanied by a great reduction in the numbers of bacteria. For use with effluents, therefore, lime alone would not seem to be a valuable germicide. Rideal states that sixty to seventy grains (850–1,000 parts) are inefficient in sterilization. Thresh believes that lime would furnish a satisfactory sterilization of effluents, but has not tried it. (Great Britain, 1902, A, Quest. 8917.)

3. Acids. — Most bacteria are much more sensitive to acids than to alkalies. This applies particularly to the typhoid and cholera germs. Rideal considers it feasible to use acids as germicides. He states that Stutzer found .05 per cent. of sulphuric acid fatal to cholera in fifteen minutes and .02 per cent. fatal in twenty-four hours; that Ivanoff found that .04 per cent. to .08 per cent. destroyed the cholera germs in the sewage of Berlin and of Potsdam; and that Kitasato found .08 per cent. sulphuric acid fatal to typhoid in fifteen minutes, a result

obtained also by Rideal himself. To furnish one million gallons of sewage with .08 per cent. sulphuric acid would require 6,640 pounds of acid, at an approximate cost of $332. Smaller amounts of acid might be used, since it would not be necessary to kill typhoid germs in so short a time as fifteen minutes; but, on the other hand, there is in most sewage a considerable amount of free alkali requiring neutralization before any effect of the acid would be obtained. On the whole, this process would seem to be an impractical one except in cases of emergency. It is interesting to note that the sewage of Worcester, Massachusetts, contains normally an average of .01 per cent. free sulphuric acid, or half enough to kill cholera germs in twenty-four hours.

4. Ozone. — Ozone has been used with more or less success in various parts of Germany, particularly at Weisbaden, for the sterilization of drinking water. Although the process has been most favorably spoken of by those in immediate care of the investigations, it has not generally been regarded as a success, and its use at Weisbaden has been discontinued. There can be no doubt as to the possibility of procuring a satisfactory effluent by this process when the water in question is a highly polluted river water. Whether the process would deal satisfactorily with a sewage effluent of considerable turbidity has not been determined. Rideal points out that ozone is but sparingly soluble. Such being the case, it might altogether fail to penetrate the solid masses in the effluent, since the rate at which a dissolved gas will thus penetrate solids is a direct function of its solubility.

The principal cause of the failure of the ozone process, however, seems to be its expense. If this is the case in water works it seems hardly possible that the process could be applied to sewage effluents as an additional safeguard after purification. There are no data at hand for estimating the cost of ozone treatment when applied to effluents. Besides the cost of treatment there is the very considerable cost of installation of the necessary machinery and towers.

5. Chlorine and Its Compounds. — Chlorine is well known as a powerful germicide. It has long been known as a bleaching agent acting upon organic coloring matter, not directly, but by means of the free nascent oxygen which it liberates from the water in which it is dissolved. It is probable that its germicidal effect is similar. In other words, chlorine and ozone come to the same thing in the end, namely, nascent oxygen. Chlorine, however, has the advantage of

more ready solubility and of cheapness. It is used technically in three forms, all of which, however, act in the form of free chlorine, and not as compounds.

(*a*) *Chlorine Gas.* — Until within recent years chlorine has been manufactured commercially by the Weldon or some similar process. In the Weldon process hydrochloric acid is made to react with a complex mixture of manganese hydroxide and lime — "Weldon mud" — the reaction being essentially

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2,$$

although in reality it is much more complex.

Recently, however, electrolytic processes have been developed by which the cost of manufacture has been materially reduced, particularly where cheap water power is available. The difficulties in the way of using gaseous chlorine are chiefly the cost of transportation, difficulty and danger in handling the gas, and the difficulty of accurately measuring the amount of gas added to the effluent. On the other hand, if the magnitude of the work would warrant the installation of an electric chlorine generating plant, there is reason to believe that there would be a great economy in the preparation and direct use of the gas, and the disadvantages noted would be obviated to a large extent. This matter of cost will be more fully discussed in another place.

(*b*) *Oxychloride Process. Hermite Process.* — The electrolysis of ordinary salt yields chlorine and caustic soda. It is claimed that if magnesium salts be present, as in sea water, a secondary reaction occurs by which there are produced certain oxides of chlorine. Three oxides of chlorine are known: Cl_2O and Cl_2O_3, the anhydrides of hypochlorous and chlorous acids, respectively, and chlorine peroxide, ClO_2. The latter is formed only under exceptional conditions and is extremely unstable. The others unite instantly with water to form the corresponding acids. There seems to be no legitimate reason for assuming the presence of any compounds in this electrolyzed sea water except compounds analogous to those which we know are produced in the case of the sodium and the calcium salts; namely, hypochlorites. The hypochlorite of magnesium seems to be an unstable compound, readily hydrolyzing to magnesium hydrate and hypochlorous acid. This fact is sufficient to account for the higher disinfectant value observed in the use of electrolyzed sea water as compared with equivalent amounts of available chlorine in the form of bleaching powder.

Rideal made an extensive series of experiments at Guildford,

England, where he was able to test the effect of the "oxychloride" treatment upon raw and septic sewages and upon effluents of primary, secondary, and tertiary contact beds. The following tabulated summary of his results will show about what may be accomplished. By the term "available chlorine" (av. cl.) is meant the chlorine value as obtained by titration with arsenious acid. The results, especially as regards the removal of *B. coli*, are all that can be desired. Examinations of the few organisms remaining in the sewages and effluents after treatment showed them to be largely organisms of the hay bacillus group, aërobic spore-forming bacteria, which are probably beneficial in the further oxidation of the organic matter. Absolute sterilization required very high concentration of chlorine.

TABLE I — SUMMARY OF RIDEAL'S EXPERIMENTS AT GUILDFORD, ENGLAND, ON THE USE OF OXYCHLORIDE IN STERILIZING RAW SEWAGE, SEPTIC EFFLUENTS, AND THE EFFLUENTS OF PRIMARY, SECONDARY, AND TERTIARY CONTACT FILTERS

Sample of	Av. cl. Parts per million.	Time of contact.	Organisms per Cubic Centimeter.					
			Total.		B. coli.		B. enteritidis.	
			Initial.	Final.	Initial.	Final less than	Initial.	Final less than
Sewage	30	4.3 hours	23,000,000	50,000	1,000,000	1.0	1,000	10.0
	50	4.3 hours	23,000,000	20	1,000,000	0.2	1,000	0.2
	70	4.3 hours	23,000,000	10	1,000,000	0.2	1,000	0.2
Septic effluent	25 to 44	1.0 hour to 4.0 hours	2,500,000 to 4,500,000	20 to 600	100,000 to 1,000,000	1.0 to 0.2	10 to 1,000	1.0 to 0.2
First contact	20	40 minutes	. .	. .	100,000	0.2	. .	. .
	20	2 hours	. .	. .	. .	. .	20 to 100	0.2
Second contact	10.6	. .	1,000,000 to 2,000,000	40	1,000,000	0.2	10 to 1,000	0.2
Third contact	2.5	1.0 hour	. .	. .	1,000 to 10,000	0.2	. .	. .
	2.5	4.5 hours	. .	. .	. . 1,000	. .	10 to 100	1.0
	0.5	0.5 hour	. .	. .	to 10,000	0.2	. .	. .
	0.5	4.5 hours	. .	. .	. .	. .	10 to 100	0.2

(*c*) *Chloride of Lime.* — Chloride of lime, so called, is a mixture of calcium hypochlorite, calcium chloride, and impurities. Its efficiency as a disinfectant is due to the action of the hypochlorite, which decomposes slowly, giving off oxygen and free chlorine. Thresh has used chloride of lime at Illford, England, for the sterilization of the effluent of a chemical precipitation plant. The addition of 140 to 200 parts of

the chloride was found to give a nearly sterile effluent after the latter had flowed in a closed conduit for a mile. Commercial chloride in this country will average 35 per cent. available chlorine. Upon this basis the amount of chlorine used was 50 to 100 parts. The chloride would, therefore, seem to be as efficient as the so-called oxychloride, and in fact is probably a similar compound.

During the past year experiments have been carried on at this station to determine the efficiency of bleaching powder in the sterilization of the effluent of a trickling filter. A preliminary series of tests was first made, covering a wide range of concentrations of bleaching powder. These tests were made in bottles. A strong suspension of bleaching powder was made up and analyzed for available chlorine by the arsenious acid method. Portions of this solution were then measured into bottles, each containing 1 liter of the effluent from the trickling filter. The available chlorine was again determined in a sample withdrawn from the bottle. Determinations of the total organisms present in the effluent before adding the disinfectant and at stated intervals thereafter were made. Plates were made with standard nutrient gelatin, incubated at 20° and counted on the third day.

The results of these tests are summarized in Table II, and in Table III are calculated into percentage figures:

TABLE II — Preliminary Tests of Efficiency of Bleaching Powder in the Sterilization of a Trickling Filter Effluent

Temperature 20°

Experiment No.	Bottle No.	Av. cl. Parts per million.	Bacteria per Cubic Centimeter. Initial.	Thirty minutes.	One hour.	Two hours.	Five hours.	Twenty hours.
1906								
I. Started February 13	Blank	0.0	80,000	. .	. .	. .	. .	640,000
	1	3.5	70,000	850	. .	500	50	50
	2	10.6	80,000	500	. .	900	290	50
	3	55.0	90,000	50	. .	180	. .	50
	4	108.0	60,000	. .	. .	. .	. .	50
II. Started February 20	Blank	0.0	133,000	. .	. .	. .	. .	. .
	1	25.0	122,000	190	90	. .	. .	. .
	2	25.0	99,000	100	180	. .	. .	. .
	3	37.0	128,000	50	80	. .	. .	. .
	4	100.0	124,000	27	36	. .	. .	. .
III. Started March 7	Blank	0.0	176,000	. .	. .	272,000	. .	. .
	1	2.0	153,000	. .	300	100	. .	. .
	2	5.0	130,000	. .	100	50	. .	. .
	3	5.0	146,000	. .	100	300	. .	. .
IV. Started March 13	Blank	0.0	80,000	. .	. .	86,000	. .	. .
	1	0.25	96,000	. .	33,000	38,000	. .	. .
	2	0.50	84,000	. .	9,100	4,600	. .	. .
V. Started March 20	Blank	0.0	230,000	. .	. .	200,000	. .	. .
	1	1.0	212,000	. .	39,000	1,900	. .	. .
	2	1.5	146,000	. .	500	100	. .	. .
VI. Started April 17	Blank	0.0	24,000	. .	. .	68,000	. .	. .
	1	5.0	25,000	. .	. .	500	. .	. .
	2	10.0	35,000	. .	. .	100	. .	. .

TABLE III — Summary of Preliminary Experiments

Experiment No.	Available chlorine. Parts per million.	Organisms Killed. Per Cent. of Initial Numbers. Thirty minutes.	One hour.	Two hours.	Five hours.	Twenty hours.
I	3.5	98.7	. .	97.8	99.6	99.9
	10.6	98.9	. .	98.9	99.7	99.8
	55.0	99.9	. .	99.9	99.9	99.9
II	25.0	. .	99.8	99.9	. .	. .
	37.0	. .	99.94	. .	. .	. .
	100.0	. .	99.97	. .	. .	. .
III	2.0	. .	99.8	99.9	. .	. .
	5.0	. .	99.85	99.9	. .	. .
IV	0.25	. .	65.6	70.9	. .	. .
	0.50	. .	89.2	94.2	. .	. .
V	1.0	. .	81.5	99.1	. .	. .
	1.5	. .	99.6	99.9	. .	. .
VI	5.0	. .	98.2	98.2	. .	. .
	10.0	. .	. .	99.6	. .	. .

These results indicate clearly the practical impossibility of obtaining a sterile effluent in this way. Neither the addition of large amounts of bleaching powder, up to 100 parts of available chlorine per million, nor the storage of the effluent for periods of time up to twenty hours proved entirely effectual. It is further shown that a concentration of about five parts per million of available chlorine and a storage period of about two hours give practically the maximum efficiency possible with the process.

Upon this basis, therefore, a practical test of the process was made. A large trickling filter at the Sewage Experiment Station, filtering raw sewage at the rate of five thousand gallons per day, was used. A solution of bleaching powder was made up in a fifty-gallon barrel of such strength that when added to the effluent at the rate of two gallons per hour it would supply the effluent with about five parts per million of available chlorine. It was not possible on such a small scale to regulate the flow accurately, and there was some variation in the amount of available chlorine found in the effluent. This value was determined each day when the samples were taken for bacterial examination. It averaged about five parts per million, and the variation was no more than may be expected in the case of a larger plant with less careful supervision.

The mixed effluent and sterilizing solution passed into a settling basin built on the principle of a Dortmund tank, and designed to give a mean storage of approximately two hours. Regular examinations of the effluent before admixture with the sterilizing solution and after this two-hour period of contact were made. The total bacteria growing upon gelatin at 20° were determined by the usual plating method.

The removal of total organisms was found to be 99.96 per cent. The determination of *B. coli* was made by the bile broth presumptive test recommended by Jackson (1906). Positive results were obtained in 33 per cent. of the tests made upon the untreated effluent at a dilution of $\frac{1}{1000000}$, indicating that the organism was present on the average to the extent of about 330,000 per cubic centimeter. After treatment positive tests were obtained in 22 per cent. of 1 c.c. samples, indicating that on the average there was one organism present in 5 c.c. of effluent. Upon this basis the average removal of fermenting organisms (presumably *B. coli*) was 99.993 per cent.

The detailed results of this series are shown in Table IV.

TABLE IV—Examinations of Effluent from Trickling Filter before and after Sterilization with Chloride of Lime, Available Chlorine, Five Parts per Million

Date.	Organisms per Cubic Centimeter.		Gas Production in Bile Broth.	
	Before treatment.	After treatment.	Before treatment. Dilution, $\frac{1}{1000000}$ c.c.	After treatment. Dilution, 1 c.c.
August, 1906.				
11	270,000	69	+ 0	+ 0
13	630,000	41	0 0	+ 0
14	135,000	406	+ +	+ 0
15	230,000	21	0 0	0 0
16	250,000	37	+ 0	0 0
18	110,000	40	0 0	+ 0
20	90,000	54	+ 0	0 0
21	220,000	22	0 0	0 0
23	. .	. .	+ 0	0 0
Average	240,000	86	33 per cent.	22 per cent.
Average removal		99.96 per cent.		99.993 per cent.

A series of laboratory experiments was carried on at the same time to determine the germicidal power of the bleaching powder solution upon *B. typhosus*. Strong bouillon cultures of this organism were made in sterile tap water. After the number of organisms initially present was determined, suitable amounts of the bleaching powder solution were added, and determinations were made of the organisms remaining alive at stated intervals. The results of these tests are shown in Table V.[1]

[1] The writers desire to express their acknowledgments to Dr. R. P. Cowles, of Johns Hopkins University, for valuable assistance in carrying out the bacteriological work involved in these experiments.

TABLE V — EXPERIMENTAL RESULTS SHOWING THE GERMICIDAL ACTION OF BLEACHING POWDER SOLUTIONS UPON B. TYPHOSUS.

Experiment No.	Available chlorine. Parts per million.	Organisms per Cubic Centimeter.							
		Initial.	One minute.	Twenty minutes.	Forty minutes.	Sixty minutes.	Two hours.	Four hours.	Twenty-four hours.
I	4.2	1,300,000	1,000,000	300,000	59,000	9,800	800	. .	15
II	5.4	5,500,000	4,450,000	1,350,000	850,000	675,000	450,000	450,000	6,000
III	4.7	1,200,000	. .	465,000	190,000	133,000	50,000	. .	54
IV	6.9	3,200,000	20,000	200	. .	300	20	. .	10
V	3.5	5,800,000	20,000	800	200	500	11	0	1
VI	3.5	3,200,000	70,000	200	100	200	26	16	8

Except in Experiment II, the reduction in twenty-four hours is practically complete, and in two hours is satisfactory for all purposes for which such treatment would be undertaken, the enormous initial numbers being taken into consideration. The phenomenon of a few specially resistant organisms is a very common one in all investigations of germicides, whether of heat, cold, desiccation, or chemical disinfection, and is particularly marked here. The results of Experiment II are in disagreement with the others. Whether they represent a specially resistant culture of the organisms or whether the results are due to some error in the experiment cannot be stated.

Summarizing, it may be said, as a result of these experiments, that a concentration of five parts per million of available chlorine from bleaching powder, acting for a period of two hours, will remove 99.96 per cent. of the total bacteria and practically eliminate the intestinal organism, *B. coli*, and any typhoid organism present.

Cost of Chlorine in Various Forms

With the electrolytic process in use at Niagara Falls, where cheap power is available, the manufacture of chlorine and of bleaching powder is carried out very cheaply. Commercial bleaching powder can be purchased in the Eastern market at about 1 cent per pound, guaranteed 40 per cent. available chlorine. In other parts of the country the additional freight charges might make the cost somewhat higher. On the convenient basis of 1 cent the actual cost of the chlorine is 2.5 cents, and the cost of adding one part per million of

available chlorine to the effluent would be 21 cents per million gallons, or $1.05 per million gallons for five parts. Bleaching powder is made by the action of chlorine upon caustic lime, so that chlorine in this form will obviously cost more than as the free gas. To develop at once its full bleaching or disinfecting action it is necessary to use it in acid solution, as is done in commercial bleaching processes. An investigation of the reactions involved leads us to believe that the total available chlorine, as indicated by the analysis, is eventually set free in a solution of organic matter, such as sewage, especially in the presence of sunlight; but it is probable that the reaction proceeds more and more slowly as it reaches the end, and that in the time available for treatment it is not safe to count upon more than 75 per cent. of the available chlorine being actually used. Rideal observed that there was an immediate loss of available chlorine corresponding roughly to the strength of the sewage or effluent under treatment, and that afterward the loss of available chlorine was very gradual, his explanation being that there were two distinct kinds of organic matter present. With the knowledge that free carbonic acid, always present in sewage, is able to react with the hypochlorite liberating chlorine, we are inclined to the view that the preliminary action noticed was due to this cause. Free gaseous chlorine, on the other hand, is all "available" and ready for immediate use. As the time element is one of immense importance in the design and cost of a sterilization plant, this item alone deserves much weight. Moreover, the use of chlorine gas possesses certain other advantages over the bleaching powder. It adds nothing else to the sewage, whereas bleaching powder adds a certain amount of insoluble material and considerable hardness. It seemed advisable, therefore, to obtain, if possible, some actual cost data on the production of electrolytic chlorine. Through the courtesy of Messrs. A. G. Paine, Jr., president, and J. R. Crocker, superintendent, of the New York and Pennsylvania Company, the following statistics have been obtained, based upon actual costs in a large paper mill using the McDonald electrolytic cell.

Each cell will produce 22 pounds of chlorine and 22 pounds of caustic soda per day of twenty-four hours, with the use of 2.08 kilowatts of current. One kilowatt hour is therefore equal to 0.46 pound of chlorine. The cost of power, made under the most favorable conditions by a modern compound condensing engine, burning "run-of-

the-mine" coal at $2 per ton, is estimated at not over $52 per kilowatt year, or 0.6 cent per kilowatt hour. The cost of chlorine is therefore about 1.3 cents per pound, a trifle over half the cost of the chlorine in bleaching powder. If, as we have intimated, this form of chlorine shall be found to be 25 per cent. more efficient than the other, and if the original cost of installation be not too great, it seems that for large works, at least, the manufacture of chlorine might well be undertaken. Even at 2 cents per pound the cost of treating a million gallons of effluent with one part per million of chlorine would be reduced to 16.6 cents, or 83 cents per million gallons for five parts. Moreover, this expense would be considerably offset by the value of the caustic soda produced at the same time.

6. Copper and Its Compounds. — Rideal has experimented recently with copper salts, and finds them efficient in the sterilization of effluents. While its expense would seem to prohibit the general use of copper, it is undoubtedly a suitable disinfectant for water cress and oyster beds.

Johnson and Copeland (1905) obtained the following reduction of total organisms in effluents:

	Copper sulphate. Rate per million.	Per Cent. Reduction.	
		Three hours.	Twenty-four hours.
First series, average of three sets	5	90.0	99.9
	10	98.0	99.95
	20	98.5	99.96
Second series, average of three sets	10	40.0	99.7
	20	60.0	99.9
	40	88.0	99.95

They find action most rapid during the first hour. They estimate the cost for chemicals alone at $5 per million gallons of effluent, treated with ten parts per million, or $10 for twenty parts, which they consider prohibitive. More experimental data on the use of copper salts are needed before we can judge of their value. Their effect will also depend largely upon the character of the water.

7. Miscellaneous. (*a*) *Permanganate.* — Potassium and sodium permanganate have been used at times for the oxidation of organic matter in streams. At London sodium permanganate is added to the Thames regularly when it becomes too foul at times of low water. The application here is to destroy odors and putrescible material, but it

undoubtedly partially sterilizes the water. Its use has been proposed for rendering effluents of chemical precipitation plants non-putrescible. The cost is greater than chlorine compounds, which would seem to be fully as efficient.

(*b*) *"Amines" Process.* — This process was developed by H. Wollheim in England. It is claimed that trimethylamine treated with lime or other alkali produces a very poisonous substance. Herring brine is used for the amine. A large excess of lime is used, and the mixture used to precipitate crude sewage. Klein made a test of the process at West Horn in 1889, and found that a clear, non-putrescent, and sterile effluent could be obtained. Similar results were obtained at Wimbledon, where the bacteria on the sewage were reduced from 768,000 to none. The sludge is also non-putrescible. The process has never been developed further. (Great Britain, 1902, A, Quest. 5206.)

Conclusions

Summarizing the more important points of the present discussion, we may state:

Ordinarily it is not the function of the sewage filter to remove bacteria from the sewage. In the case of the modern rapid filters, we are not at all certain as to the fate of the dangerous germs of disease.

Where extensive shellfish interests are at stake it will sooner or later become necessary to protect the neighboring waters from pollution, and in this case the total absence of pathogenic bacteria must be assured.

This result may be attained by the ultimate use of sand filters or by chemical sterilization.

Among the possible agents for use in sterilization, chlorine, either as chloride of lime or as free gaseous chlorine, appears to have the highest cost efficiency. An amount of the former which will yield five parts per million of available chlorine was found to have destroyed 99.96 per cent. of the total bacteria and practically all of the *B. coli* present in the effluent of a trickling filter treating crude Boston sewage, the time of contact having been two hours. The estimated cost of such treatment is $1.05 per million gallons of sewage.

The use of gaseous chlorine, manufactured at the disposal works by electrolytic methods, would in the case of larger works consider-

ably reduce this cost. An approximate estimate places the cost of such treatment at about 85 cents per million gallons of sewage, allowing five parts of chlorine per million. It is probable that the chlorine in this form is somewhat more efficient.

The process as thus outlined is entirely feasible, and in the case of large works it is cheaper than sand filtration. Further experiments upon a large scale are now under way to test the results of these experiments and to get more accurate cost and efficiency data.

Among other agents which may be used, copper sulphate seems to be the most promising, and further experimental data are needed to show what efficiency may be expected from its use.

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CONTRIBUTIONS FROM THE LABORATORY OF SANITARY CHEMISTRY

XI

ANALYSES OF AMERICAN MALT VINEGAR

BY A. G. WOODMAN AND G. P. SHINGLER, JR.

THE composition of cider vinegar as made in this country has been carefully studied, and several valuable contributions to our knowledge of it have been made, notably by Smith [1] and by Leach and Lythgoe.[2]

Published analyses of malt vinegar, on the other hand, are comparatively rare, being limited practically to the few analyses made by Hehner [3] in 1891, and extensively quoted in the literature, and to the analyses given by Allen in his "Commercial Organic Analysis." [4] Moreover, these refer to English samples, the only analyses of American specimens being three published by Smith in the paper previously mentioned.

On this account, and because malt vinegar is an article of food for which the demand in this country is increasing, it seemed desirable to undertake the analysis of several authentic samples of American origin.

The samples, seven in number, were secured directly from the manufacturers, who were aware of the purpose for which the vinegar was to be analyzed, and who signified their willingness, if desired, to furnish a sworn guarantee of the purity of the product. Sample G was made by the spontaneous fermentation of sour ale, and while the results are published as a matter of general interest they are not included in the final averages.

METHODS

Specific Gravity. — This was determined with a pyknometer at 15.5°.

Total Acid. — 5 c.c. were diluted to 200 c.c., nearly neutralized

[1] J. Am. Chem. Soc., 1898, 20, 3.

[2] J. Am. Chem. Soc., 1904, 26, 375.

[3] Analyst, 16, 82.

[4] Edition 3, Vol. I, p. 470.

with $\frac{N}{10}$ sodium hydroxide, heated to boiling to expel carbon dioxide, and the titration finished in the hot solution, using phenol-phthalein as indicator.

Solids. — 5 c.c. were measured into a tared, flat-bottomed platinum dish, heated for two hours in contact with the steam of a boiling water bath, and weighed.

Ash. — 25 c.c. were evaporated to dryness and carefully incinerated in a muffle. The contents of the dish were then treated with boiling water, filtered through an ashless filter, and the residue washed with hot water. The filter and residue were dried and ignited in the dish, giving the weight of insoluble ash.

Alkalinity of Ash. — This was determined on the water-soluble ash, and on the insoluble portion by boiling with an excess of $\frac{N}{10}$ hydrochloric acid and titrating the excess of acid with $\frac{N}{10}$ sodium hydroxide and phenol-phthalein.

Soluble Phosphoric Acid. — The solution of the ash from 25 c.c. of the sample was evaporated to dryness, the residue taken up in boiling water, and the phosphoric acid determined by titration with uranium acetate.

Insoluble Phosphoric Acid. — The insoluble ash was moistened with dilute nitric acid, evaporated, carefully incinerated, and taken up in boiling distilled water. The titration with uranium acetate was carried out as before, the uranium solution being standardized in this case against pure tricalcium phosphate.

Polarization. — 50 c.c. of vinegar, clarified with 5 c.c. of basic lead acetate, was filtered and the filtrate polarized in a 220 mm. tube. The polarization is expressed in degrees Ventzke for 200 mm.

Reducing Sugar after Inversion. — 25 c.c. were diluted to 50 c.c., and 5 c.c. of concentrated hydrochloric acid were added. The solution was heated to 70° C. in three to five minutes, maintained at that temperature for five minutes, cooled, nearly neutralized with potassium hydroxide, and made up to 100 c.c. Reducing sugar was determined in an aliquot part by the Defren-O'Sullivan method.[1]

Total Proteids. — The determination was made by the Kjeldahl method, the factor 6.25 being used in calculation.

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[1] Tech. Quart., 1897, **10**, 167.

Results

Table I is a compilation of the previous analyses; the results of the present investigation are given in Table II. All results, unless otherwise stated, are given in percentages.

TABLE I

	Specific gravity.	Acetic acid.	Total solids.	Ash.	C.c. $\frac{N}{10}$ acid for alkalinity of soluble ash.	C.c. $\frac{N}{10}$ acid for ash of 100 grams vinegar.	P_2O_5, mgs. per 100 grams.	Albuminoids.	Analyst.
1	. .	3.07	3.26	.39	. .	13.58	130.0	. .	Hehner
2	. .	2.88	2.72	.41	. .	15.85	120.0	. .	Hehner
3	. .	3.70	4.01	.31	. .	6.98	130.0	. .	Hehner
4	. .	6.48	2.44	.31	. .	14.34	88.0	. .	Hehner
5	. .	5.73	2.46	.47	. .	16.79	92.0	. .	Hehner
6	. .	4.16	1.68	.22	. .	3.21	96.0	. .	Hehner
7	. .	3.79	4.23	.32	. .	14.34	67.0	. .	Hehner
8	1.0205	6.61	2.81	.55	. .	21.26	66.0	.76	Allen
9	1.0170	6.39	2.67	.34	. .	19.04	77.0	.62	Allen
10	1.0228	5.26	3.96	.40	. .	24.55	93.0	.60	Allen
11	1.0160	4.86	2.31	.47	. .	. .	57.0	.62	Allen
12	. .	5.90	2.21	.28	6.0	. .	12.5	. .	A. W. Smith
13	. .	5.16	2.67	.26	6.0	. .	9.0	. .	A. W. Smith
14	. .	4.40	2.04	.23	5.6	. .	9.2	. .	A. W. Smith
15	. .	4.01	1.75	.20	4.4	. .	9.5	. .	A. W. Smith

Remarks. — In this table the figures for the alkalinity have been recalculated in several instances in order to afford a uniform basis for comparison. All the samples are of English origin except 13, 14, and 15, which are American. The first seven are supposed to be made from malt only, 8, 9, 10, and 11 from mixtures of malted and unmalted grain, the starch entirely hydrolyzed by diastase.

TABLE II

Sample.	Specific gravity, 15.5° C.	Total acid as acetic.	Total solids.	Ash.	Ash soluble in water.	Insoluble ash.	Alkalinity of soluble ash, c.c. $\frac{N}{10}$ acid for 100 grams vinegar.	Alkalinity of insoluble ash, c.c. $\frac{N}{10}$ acid for 100 grams vinegar.	Soluble P_2O_5, mgs. per 100 grams vinegar.
A	1.0271	5.70	4.88	.43	.29	.14	15.18	15.94	13.32
B	1.0143	5.50	2.02	.27	.14	.13	5.35	13.03	16.66
C	1.0131	4.53	1.60	.25	.15	.10	9.88	14.30	36.36
D	1.0121	5.21	1.55	.16	.11	.05	4.35	8.03	10.40
E	1.0188	6.81	2.51	.21	.13	.08	3.50	19.09	32.02
F	1.0128	4.60	1.37	.19	.15	.04	12.05	9.32	47.78
G	1.0235	6.04	3.32	.17	.05	.12	3.40	20.39	27.74
Maximum . .	1.0271	6.81	4.88	.43	.29	.14	15.18	20.39	47.78
Minimum . .	1.0121	4.53	1.37	.16	.11	.04	3.40	8.03	10.40
Average . .	1.0159	5.48	2.46	.24	.14	.09	7.67	14.58	23.47

TABLE II — *Continued*

Sample.	Insoluble P_2O_5, mgs. per 100 grams vinegar.	Polarization.	Reducing sugars (maltose) before inversion.	Reducing sugars (dextrose) after inversion.	Proteids (N × 6.25).	Per cent. ash in total solids.	Per cent. reducing sugar in total solids.	Per cent. P_2O_5 in total solids.	Ratio soluble to insoluble P_2O_5.
A	22.86	6.05	2.30	1.84	.59	8.81	47.13	0.74	1 : 1.716
B	8.78	0.31	1.05	0.83	.53	13.37	51.98	1.26	1 : 0.527
C	43.03	1.75	0.90	0.61	.29	15.63	56.24	4.60	1 : 1.185
D	8.97	2.56	0.60	0.40	.14	10.32	38.72	1.25	1 : 0.863
E	17.42	2.76	1.07	0.77	.22	8.38	42.63	1.97	1 : 0.534
F	19.47	0.06	1.01	0.63	.19	13.87	73.72	4.91	1 : 0.407
G	25.99	3.18	2.84	2.09	.62	5.11	85.55	1.32	1 : 0.937
Maximum . .	43.03	6.05	2.84	2.09	.62	15.63	85.55	4.91	1 : 0.407
Minimum . .	8.78	0.06	0.60	0.40	.14	5.11	38.72	0.74	1 : 1.716
Average . .	20.93	2.38	1.39	1.02	.37	10.78	56.56	2.29	1 : 0.890

Contribution from the Department of Geology

REPORT ON THE GEOLOGICAL EXCURSION THROUGH NEW MEXICO, ARIZONA, AND UTAH, SUMMER OF 1906

By DOUGLAS WILSON JOHNSON

In connection with the study of certain problems in physiographic geology, and for the purpose of supplying certain deficiencies in our teaching collection in that subject, I some time ago formulated the plans for a wagon trip through some of the more inaccessible parts of the Southwest. It seemed to me that such a trip would make possible the collection of data which might solve, or at least make desirable contributions to, some of the problems in connection with the history of the plateau province of Arizona and Utah, the origin of the volcanic buttes in the Mount Taylor district, New Mexico, and the character and origin of the Basin Ranges of Utah; also the collection of valuable illustrative material for the courses in topographic, lithologic, and paleontologic geology. The execution of the plans for such an excursion was made possible last spring by an award of $250 from the Austin Fund, a grant of similar amount from the Sturgis-Hooper Fund of Harvard University, and by private gifts from friends of the Institute amounting to $500.

Dr. H. W. Shimer, of the Institute Geological Department, and Mr. C. H. Decker, a graduate of the Columbia University School of Mines, looked after the stratigraphic and economic geological problems more particularly, Dr. Shimer securing much material which will add greatly to the value of the Institute's teaching collections, and which will form the basis of future publications. The main energies of the party, however, were directed to the study of problems and the collection of material which were related to physiographic geology.

The party left Albuquerque, central New Mexico, on the 31st day of May, with camp outfit and provisions for a ten days' trip in the

Mount Taylor district. This region was made classic by the report of Major C. E. Dutton on the volcanic necks and other volcanic features there represented. These necks were described as showing vertical columnar structure in many cases, being of enormous size and nearly cylindrical in shape or somewhat elongated in one direction, while the adjacent sedimentary beds were not much disturbed. In recent years some doubt had been expressed as to the interpretation of these features, it being argued that vertical columnar structure should not be expected as a prominent feature in volcanic necks, but was rather indicative of some other origin for the famous buttes; that it was difficult to understand how a cylindrical neck or plug could be forced up through sedimentary beds, especially if those beds were not profoundly disturbed. Professor Jaggar has concluded that the Mato Tepee, or Devil's Tower, of Wyoming (fully described in his report on the geology of the Black Hills), a butte which bears a striking resemblance to some of the New Mexico types, must be the remnant of an old laccolith, basing his conclusion on the vertical columnar structure, the undisturbed sediments at the base of the tower, and the association of the butte with undoubted laccoliths still well preserved.

It was in the hope of securing data bearing on this problem that we examined a number of the finest examples of the buttes in the Mount Taylor district. The study led to the following conclusions: (1) The buttes are undoubted volcanic necks of large size, one of them rising over 2,000 feet above the surrounding valley lowland. (2) Many of them show good columnar structure more or less nearly vertical; it is believed that this position is due to the floor of the crater's acting as the cooling surface for the upper portion of the neck, at least, rather than the probably heated walls of the conduit up through which the lava came; the columns developing at right angles to the cooling surface would thus be vertical, instead of radial or irregular, as formerly supposed. (3) The necks are more or less cylindrical in shape, and have come up from unknown depths without in the least disturbing the surrounding sediments in most cases, thus showing that enormous plugs may force a clean passage through sedimentary rocks, however difficult the process may be of explanation (4) The age of the rocks, the general geology and physiography of the region, and the detailed character of the necks were studied. Typical rock specimens, fossils, and photographic views were obtained. The results of this study will be published during the year under the title, "The Volcanic Necks of the Mount Taylor Region, New Mexico."

After returning to Albuquerque, our party went by rail to the Big Bug mining district, some twenty-five miles southeast of Prescott, Arizona, where we made our headquarters in the northern end of the Bradshaw Mountains while outfitting for the trip across the deserts to the north. We experienced considerable difficulty in securing suitable horses and wagons, but after some delay procured an outfit of five horses, two wagons, the necessary saddles, tent, bedding, provisions, etc., and on the 19th of June started northward. We soon turned eastward to the valley of the Verde River, making a study of the large limestone series of that district with a view to determining its age and origin. Thence turning northeast we followed up Oak Creek to the foot of the great Mogollon escarpment, which terminates the plateau district on the south, and after a few miles of the steepest and roughest road encountered during the whole summer reached the summit, where we could look far to the northward and see the San Francisco Mountain rising high above the surrounding forest-covered plateau surface, while below us to the south lay the arid lands of the basin region. Here we were able to trace the relations of several great faults which help to determine the rectangular pattern of the southern margin of the plateau in this region. Continuing northward to Flagstaff, we found extensive lava flows covering portions of the plateau which do not appear on the previous maps of the region. From Flagstaff we turned southeast to Walnut Canyon, the region of some of the best cliff-dwellings in the Southwest. Dr. Shimer made a detailed study of the geological section exposed in the canyon walls, collecting a series of characteristic fossils and determining the character of the beds which weather into overhanging ledges and thus afford the conditions utilized by the cliff-dwellers in making their homes.

We next passed around the western base of the San Francisco Mountain, and established a camp well up the northwest slope. From this camp we made a two days' trip with pack outfit to the summit of the old volcano to study the effect of ancient glaciation at the highest levels. Although so far south, the peak rises to such an altitude (12,794 feet above sea level) that its summit was occupied by a local glacier during the glacial period, this glacier eroding a splendid cirque in the very centre of the volcano, and leaving a prominent terminal moraine a short distance down the valley into which the cirque opens. Even today the snows lie on the higher levels and in sheltered places

until well into the summer, our camp on the night of July 6 being pitched between two snowdrifts over 10 feet high. Five days later we were in the bottom of the Grand Canyon, 10,000 feet lower, our party almost prostrated by the intense heat.

From the San Francisco volcano we went to a point near Grand View on the rim of the Grand Canyon of the Colorado, where we established a camp for several days. After visiting several points on the rim of the canyon, we descended the old abandoned Red Canyon trail, spending two nights and parts of three days in the Grand Canyon, returning to the summit of the plateau by the Grand View trail. We then returned to the northern side of the San Francisco group, where we investigated a recent cinder cone and lava flow, so recent, in fact, that erosion has as yet produced no effect on either cone or flow, both being perfectly formed, dense black in color, and fairly free from soil or vegetation. Studies were made also of numerous other cones and flows throughout the plateau region, resulting in the establishment of the fact that the so-called "period of basalt outflow" is really divisible into at least five or six different periods, with long erosion intervals between them. Collections of fossils and rock specimens from the Grand Canyon and other parts of this district were made.

Crossing eastward to the Little Colorado River, and then northward to the trading post at Tuba, we secured our last supply of grain and provisions before entering on the most strenuous part of our journey, the crossing of the Painted Desert. Already we had suffered some difficulty in securing water fit to drink and sufficient grass for the horses. At Tuba we were disappointed to find no grain, except a little Indian corn, which the horses did not seem to regard with favor. With little prospect of grass on the desert, the outlook was discouraging. The weather was now intensely hot, so that we found it advisable to travel mainly at night, resting during the day. Accordingly we usually arose about three or four in the morning, drove until the heat became oppressive, rested until six in the evening, then drove until well into the night, or until we lost our way in the darkness. During the middle of the day we erected a canvas awning to protect ourselves from the sun, but even in the shade thus afforded our thermometer registered 115° and we found it difficult to sleep.

We secured good water at Willow Springs, a short distance from Tuba, and began the journey northward along the western base of the Echo Cliffs. These cliffs are produced by erosion on an eastward

dipping monocline of sandstone, but have a much sharper form and steeper back slope than would appear normal for the gentle monoclinal dip. This sharpness of form had been noted by Professor Davis, of Harvard University, on an excursion some years before, and tentatively ascribed to possible faulting along the back slope of the monocline. Several traverses across the monocline at critical points showed the absence of any such faults, but revealed the fact that cross bedding at high angles and with rather uniform eastward dip caused the rocks to weather with steep eastward slopes, thus determining the peculiar topographic feature observed in the cliffs. Numerous landslides on a large scale were observed, thus confirming the previous observations of Professor Davis regarding the recent revival of erosion in the Grand Canyon region, with consequent undermining of previously graded slopes, causing extensive landslides in the areas near the revived streams.

By the time we reached the crossing of the Colorado River at Lee's Ferry, near the Utah line, our horses were pretty well exhausted, owing to the hot weather, lack of grain, sandy roads, and scarcity of grass, good grass being found at only two points along the road from Tuba. At Lee's Ferry we had counted on obtaining grain, but were greatly chagrined to find that the supply on hand at that point had been nearly consumed, so that the best we could do was to secure twenty-five pounds of oats, this to last five horses for over one hundred miles of desert and mountain roads!

Ten miles beyond the ferry we found ourselves facing a serious problem. The horses first stumbled repeatedly, then stopped short and refused to go another step. There was no grass, and it required a hunt of several hours to find a little pool of salty water and get the horses to it, after having first taken them out of the harness and let them rest. That evening we succeeded in getting them a little farther, but found no grass or water. The next morning we managed to reach good water and a little grass. Here it became necessary to leave one horse and one of the wagons behind and pull the other wagon by means of four horses. Walking ourselves, we were thus able to make about twelve miles, over very sandy roads and under an intensely hot sun. Returning with the horses the second day, the other horse and wagon were brought up, this method being persisted in until the foot of the Kaibab plateau on the western side of the desert was reached, an average advance of about six miles a day being made. After a short rest at a spring at the foot of the Kaibab, the horses were able to

pull the wagons, one at a time, up to the higher country on the summit, where we found better grass. The Kaibab plateau and the Kanab desert were crossed with less difficulty, although the long delay had so far exhausted our own store of provisions that the members of the party had to get along with scanty rations the last four days before reaching a new base of supplies.

In spite of the difficulties encountered this part of the trip was most profitable. We were able to make a study of the streams which are dissecting the east Kaibab monocline, and to discover marked differences between the lower and upper courses of the streams, indicating two distinct erosion periods in the development of the region. This conclusion was confirmed by the study of certain terraces discovered farther south along the monocline and by a consideration of the relation of one of the larger valleys to the monocline, all of which features offer strong evidence in favor of the recently proposed theory that the faults and folds of the plateau province are much older than the present Colorado River, as opposed to the former belief that the river's course was first established and that the faults and folds are of later development.

From Kanab, in southern Utah, our party went north to Upper Kanab to study the terraces which terminate the high plateaus on the south. The Tertiary beds, forming the highest part of this series, have been considered of lacustrine origin until late years, when the possibility of a subaërial origin has been entertained by some observers. We secured evidence, both here and farther north, strongly indicating a subaërial origin. The origin of the Triassic and Jurassic beds are also in doubt, and we made some studies as to detailed structures which we hope will aid in solving this problem. Collections of the rather scarce Jurassic fossils were made, and some points of interest regarding lava flows in the valleys noted.

Returning to Kanab, we then went southward across the Uinkaret desert to the lower portion of the Toroweap valley near the Grand Canyon. This region was of special interest, as offering undoubted evidence as to the age of two of the great faults of the plateau province. The region being difficult of access on account of the scarcity of water, evidence believed to be available had not yet been secured, and to supply this lack we attempted the trip. Dutton reported that all of the faults of this region were topographically recent, that wherever the faults were present cliffs of the upthrow side overlooked the lower

downthrow side, and that the Sevier and Toroweap faults in this special district were separate and distinct. Professor Davis has recently advanced the theory that the faults are much more ancient, so ancient, in fact, that erosion has once obliterated the topographic effects of faulting by leveling off the country; while recent erosion, removing the soft beds, has caused the reappearance of fault line cliffs wherever the old faulting brought hard and soft beds opposite each other, the cliffs thus facing toward the upthrow in some cases, toward the downthrow in others. Thus it was shown that the cliffs of today are often located on the side where the lowland was originally found, while the lowland of today has been worn out of the rocks which were faulted up, reversing the original topographic effects of faulting. Professor Davis further believed that the Sevier and Toroweap faults were continuous, being one and the same.

A somewhat detailed study of the region in question enables us to add a considerable amount of evidence which strongly corroborates the theory of a very great age for the faults, and which makes the theory of recent faulting wholly inadmissible. A traverse of some of the more inaccessible parts of the region, however, showed that the two faults were quite distinct, overlapping each other for many miles, but the Toroweap being from six to fifteen miles or more west of the southern extremity of the Sevier. The age of a part of the rock series of this region is in doubt because of the scarcity of fossil remains. We were fortunate in securing some fossils from the doubtful strata, which we hope will serve to establish their age more definitely.

After returning from the Toroweap country we went westward to the Hurricane fault, and spent several days in camp on the bank of the Virgin River, waiting until one of the greatest floods in the river's history should subside sufficiently to enable us to ford. This enforced delay gave time for a careful study of the features of the fault scarp for several miles south of the river. This region has been described in some detail by Messrs. Huntington and Goldthwait in an admirable paper. They established the occurrence of two distinct periods of faulting along the great fracture with an intervening erosion period. A careful study of the relation of certain lava flows to the fault enabled us to discover a third period of movement or faulting quite as distinct as the two previously noted, with long time intervals separating it from those other periods. The relation of a number of successive lava flows and their effect on the former topography were worked out.

Northward from the Virgin our course lay along the foot of the western rim of the high plateaus on the eastern border of the Great Basin region. We traced the Hurricane fault for a hundred miles or more to the northward, studying the details of the faulting in many different localities. Recent faulting was discovered along the western side of Round Valley; the stratigraphic series of that region was found to be quite unlike the representations on earlier maps, and the region was remapped as far as practicable. Some fossils were collected from the more recent members of the series. Collections of rhyolite, trachyte, and andesite from type localities were made for the purpose of supplementing the Institute study series. The character of the Tertiary beds in several regions was studied with regard to the question of their origin, and numerous observations of miscellaneous geological features were noted.

As we neared the Salt Lake City region we had opportunity to observe the topographic features of the ancient shore lines of the former Lake Bonneville, type examples of dissected fault block mountains, and other features which have made this classic ground for all students of geology. The numerous photographs and sketches that were made of these typical features will add much to the effectiveness of the courses in topographic geology.

In the villages and towns just south of Salt Lake City the outfit was disposed of and the party disbanded. Dr. Shimer went to the Yellowstone National Park for a short trip, Mr. Decker to the Bingham mining district, while I returned east by way of Butte, Montana.

It will be seen that the results of the expedition include the collection of data bearing on a number of special problems of some scientific importance, as well as a variety of miscellaneous observations which should be permanently recorded. It is proposed to publish discussions of the larger problems as separate reports during the coming year in different geological journals, and the miscellaneous observations, together with a brief abstract of the larger problems, as one report.

Our party was in the field nearly four months, traveling over fifteen hundred miles by wagon and probably at least three hundred more on horseback.

THE TEACHING OF BIOLOGY AND SANITARY SCIENCE IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

By C.-E. A. WINSLOW

The early history of the Biological Department at Technology is a history of men who builded better than they knew, and whose work has been justified to an extent far beyond their vision by new and unexpected developments of applied science. Courses in zoölogy, botany, paleontology, physiology, and comparative anatomy were included in the first annual catalogue of the Institute, issued in 1865; but these subjects had at that time little direct connection with a "school of industrial science." It is probable that President Rogers believed, as the faculty of the Institute have ever since held, that not only chemistry and physics (with its varied developments in mechanics and hydraulics and electricity), but geology and biology as well, should form integral parts of a liberal scientific curriculum. Their view is one which the lapse of time has only served to justify; but beyond this general aspect thirty years of progress have extended the domain of biology into new fields of direct technical application.

The earliest graduates of the Institute in natural history became teachers and investigators; and this is one of the avenues of usefulness to which work in biology at the Institute has ever since led some of its students. Both men and women graduates of the course have found congenial openings in education, and the department is represented on the faculties of many colleges and universities. Another important contingent of students has received special instruction, coming from the secondary and normal schools about Boston to take particular courses adapted to their needs. The number of teachers working as regular or special students in the biological laboratories of the Institute is somewhat less today than it was ten years ago, but the opportunity still lies open for a peculiarly helpful mutual relation between the Institute and the public school system.

The training of teachers is, however, one of the less important phases,

of the work of the Biological Department. When General Walker became President of the Institute he opened for it a new line of usefulness. Professor W. T. Sedgwick was called from Johns Hopkins in 1883 to take charge of the biological side of natural history, the Course VII of that day. Soon after, the name of his department was changed to biology, and its work was reorganized, with the aim of making it a preparation for the subsequent study of medicine. President Walker said of this new adaptation of the department: "The cultivation of the perceptive powers, the systematic practice of the art of observation, the use of instruments of precision, the early familiarity with the structure, habits, and workings of living objects, which are involved in the course, must be conceded to afford the kind of training best suited to enable the scholar to pursue the subsequent study of medicine with the greatest advantage, and cannot fail to prove of peculiar value to the physician in his professional practice."

There can be no doubt that a mastery of biology offers a good preparation for the study of medicine. Modern theories of health and disease require a sound biological conception of the organism and its relation to the environment. Modern advances in clinical diagnosis and therapeutics demand an increasing knowledge of bacteriology and physiological chemistry. Johns Hopkins recognized these facts several years ago by requiring the completion of special work in biology before entrance to the medical school; and requirements of this sort are likely to become more general.

The main development of biological work at the Institute has, however, followed another line; one which could not possibly have been foreseen at the time it was first organized, but one for which it found itself most fortunately prepared when the emergency arose — the science of bacteriology and micro-biology.

The connection between microbes and fermentation had been demonstrated by Pasteur before 1870, and his studies of the silkworm diseases which ravaged the great industry of the south of France pointed to bacteria as the cause of these maladies. Between 1875 and 1878, Robert Koch definitely proved that splenic fever was caused by a specific bacterium. It was only in the eighties, however, after Koch had devised the solid culture method of isolating and cultivating bacteria, that the science of bacteriology began to make rapid progress. The germ of tuberculosis was discovered in 1882, and the determination of the organisms which cause cholera, diphtheria, tetanus, and typhoid fever followed very quickly.

Just at this time the attention of the authorities of the state of Massachusetts was being turned toward the sanitary condition of the water supplies and rivers of the commonwealth. In 1887 Professor T. M. Drown, then head of the Chemical Department of the Institute, was asked to conduct, under the auspices of the State Board of Health, an exhaustive investigation of the water supply problems of the state. Professor William Ripley Nichols had also taken a keen interest in the new developments of sanitary science; and on his death in Europe, after a summer (1886) spent in the study of laboratory methods in the older universities, some tubes of the new Koch gelatin medium were found among his effects and sent over to the Institute. The interest with which this was received and the hesitation as to just how it was to be used (since the gelatin had become liquefied *en route*) are still remembered in the Biological Department. It was not long, however, before the new methods were mastered. In 1888 the first course in bacteriology was offered by Professor Sedgwick, and in the same year the now classic biological studies of the Lawrence Experiment Station were placed under his direction.

President Walker grasped at once the potential importance of these new lines of investigation. In 1888 he said in his annual report, speaking of sanitary bacteriology: "The great advances recently made in this line of investigation, and the almost limitless possibilities of the future in this respect, have not only caused the minds of many of our students to turn in that direction, but have created a demand from the outside for skilled bacteriologists, which up to this time the Institute has not been able fully to meet." Two years later he again pointed out the growing promise of this field of applied science in relation to "the activity of soils, the fixation of nitrogen, the preservation of foods, the preservation of timber, the purity of public supplies (such as air, water, milk, and ice), as well as the more urgent and difficult problems of drainage, sewerage, and the public health."

It was a clear vision that could grasp the close relation of bacteriology to such varied fields of applied science in the year 1890. After fifteen years many of these potential applications are still made only in tentative and experimental fashion. The study of the nitrogen-fixing organisms, which Mr. Edward Atkinson called the greatest discovery of the nineteenth century, has scarcely yet begun to bear fruit. Our telephone and telegraph companies still renew their poles once in eight years instead of employing an expert to study the organisms which rot

them away at the surface of the ground. In many directions, however, much progress has been made. Denmark took the lead in applying biology to industry in its great breweries; and the first course of instruction in this country on the microörganisms of fermentation, offered at the Institute in 1894, was founded on a study of the methods in use at Copenhagen. Today it is universally recognized that the secret of success in the brewing industries lies in the cultivation of desirable forms and the elimination of "disease" yeasts and bacteria. In the dairy the same thing is true. The harmful fermentations of milk, butter, and cheese, as well as the normal ripening of the last two products, all depend on certain microörganisms. Those which are desirable may be isolated and inoculated in pure cultures, as has recently been done with success at Wesleyan University in the case of certain cheeses. Those which are harmful may be forestalled by controlling the conditions of manufacture according to principles determined from experimental investigations. In canning and food preserving, important aid has been furnished by researches carried on at the Massachusetts Institute of Technology and elsewhere. In the tanning industry and in the preparation of fibres by various macerating processes, practical men are turning to experts for assistance. In tobacco curing and in the manufacture of various acids and dyestuffs promising fields are opening up, as yet almost unworked.

Bacteriology in its relation to the public health has developed even more rapidly than in its application to the arts and industries. A whole field of novel sciences has grown up, bound together by the fact that all bear on a single biological problem — the adaptation of the human mechanism to its environment, and in particular in relation to certain microparasites. Taken together they form what is practically a new profession, founded on its own special basis of pure knowledge — the profession of sanitary science. The care of the public health has ceased to be merely a subsidiary function of the practice of medicine. Like physiology and anatomy and bacteriology, and many other independent sciences, it owes its inception largely to the spirit of scientific research and the spirit of public service which the medical profession has always manifested in so splendid a degree. Medicine is the mother of sanitary science. It is, however, a token of wisdom in mothers to recognize the moment when their children have attained their majority; and the time has now clearly come when sanitary biologists and sanitary engineers may stand on their own feet. Professor Sedgwick, in an address

before the American Public Health Association, indicated the striking readjustment which has almost imperceptibly taken place in the relation between medical practitioners and the public health. He points out first that curative and preventive medicine, or hygiene, are today widely separated, and second that even the sphere of hygiene is naturally separable into two distinct hemispheres, one dealing directly and chiefly with individuals or masses of individuals, the other directly and chiefly with their environment.

"It is today absurd for the average well-trained medical student to think of becoming an expert in such branches of hygiene as water supply, sewerage, heating and ventilation, street building, street cleaning and watering, garbage collection and disposal, gas and other forms of light supply, ice supply, milk supply, the abatement of nuisances, etc. These belong rather to the sanitary engineer, sanitary chemist, and sanitary biologist; to sanitation rather than hygiene.

"Closer to the physician's own work, and yet almost a science in themselves, are the problems of personal hygiene — muscular exercise, sleep, foods and feeding, bathing, clothing, mental work, and the like. Halfway between personal and public hygiene lie such subjects as school hygiene and school sanitation, epidemiology, quarantine, the control of foods and drugs."

Administrative positions in connection with sanitary science and the public health demand a knowledge of the whole field, but the man of executive ability will generally reach the top by way of a sound training in one of three narrower paths which lead to it. These three primary careers are those of the physician, the laboratory expert, and the engineer.

That part of public hygiene which falls generally to the town or city board of health is concerned chiefly with the control of the contagious diseases, and includes diagnosis by inspection and laboratory examination, isolation, disinfection, and serum therapy. The staff of a city health office includes, besides the subordinate inspectors, experts of two types. For clinical recognition of such diseases as smallpox and leprosy, for medical inspection of schools, and for the administration of vaccine and antitoxin, men trained as expert diagnosticians are required; and these must be primarily physicians.

On the other hand, the methods of parasitology which are used for the laboratory diagnosis of disease demand no special medical training, but a general foundation of chemistry and histology and bacteriology, which may be gained much better at a scientific school than in an

institution devoted to the teaching of medical practice. The preparation of serums and vaccines demands specialization along lines of pure bacteriology, and not of medicine. The testing of disinfectants and the various special problems which come to the laboratory of a health board are not medical problems. All these fields of expert work, along with the bacteriology of milk and the chemistry and bacteriology of sewage and water, belong to the trained laboratory specialist, who represents the newer applications of pure science to the work of public hygiene. The formation of the Laboratory Section of the American Public Health Association, devoted to "the theory and practice of bacteriology, chemistry, etc., as applied to the advancement of sanitary science," and the admirable work which that section has accomplished offer a good index of the growth of this profession.

There remains, thirdly, the engineer, the man who deals directly with the inanimate environment and remodels it in accordance with the advice of the physician and the laboratory expert. Sanitary engineering has risen to a supreme importance, with the aggregation of masses of people in great cities, which makes the problem of healthful conditions at once more difficult and more imperative. The city is an organism which demands as the first essential for its life a supply of pure water, food, and air, and the removal of its waste products. The purification of water supplies, by the English process of slow filtration through sand or by rapid mechanical filters of the American type, is a pressing need for a large majority of the cities in the United States. It requires preliminary expert surveys, expert construction, expert operation and maintenance. A good air supply is as vital a necessity as a good water supply. We breathe eighteen times a minute and do not drink as many times a day; tuberculosis carries off ten times as many victims as typhoid fever. The erection of sanitary tenements, the ventilation of factories, and the elimination of the dust and dampness and poisonous fumes which cause an excess of phthisis in the "dangerous trades" demand scientific research and skilled construction. The removal of wastes is no less important than the supply of air and food. The pollution of streams and estuaries, with the consequent danger to water supplies and to shellfish industries, is a problem of the first magnitude. Columbus, Ohio, has set the example, which many other cities must follow, of an expert preliminary investigation of the local problem of sewage disposal; for the modern methods of sewage treatment are technical processes which require delicate adjustment. In the treat-

ment of industrial wastes, which now destroy many streams instead of being so utilized as to prove a source of profit, there is much to be done. Scientific garbage disposal in the United States demands expert investigations, which have so far been almost wholly lacking.

For the carrying out of this great sanitary campaign able and well-trained recruits are needed. It is the chief aim of the Departments of Biology and Sanitary Engineering of the Institute to furnish these recruits. The Biological Department aims to develop the first, the laboratory expert, who in some cases of special aptitude will later become a health officer or administrator. A good foundation of general chemistry and bacteriology leads to a training in the chemistry and bacteriology of air, water, and food, chemical and microscopical examination of foods and drugs, the principles of sanitary science and municipal sanitation, vital statistics, and the study of parasitology as applied to the laboratory diagnosis of the infectious diseases. Instruction in the bacteriology of sewage and water has so far been carried forward, parallel with the best current progress in that science. The staff of the department must, however, be enlarged in the near future if it is to maintain a similar leadership in some of the newer outgrowths of the science. In the training of laboratory experts in biology there should be sound general instruction in the complex problems of immunity and serum therapy; and there should be the most thorough technical training in the methods and results of the new science of the parasitic *Protozoa*, which is probably as full of possibilities today as was the science of bacteriology twenty years ago. In both these branches the Institute needs instruction by specialists who are advancing their own lines of study by productive research.

For the engineering work of the campaign against disease the Department of Sanitary Engineering has been organized, founded on the triple base of engineering, chemistry, and biology. Its students are first soundly trained along civil engineering lines, in surveying, railroad and highway engineering, stereotomy, applied mechanics, structures, and hydraulics. With these, the rudiments of chemistry and biology are also taught, since the sanitary engineer must be to some extent a chemist in order that he may plan and interpret sanitary analyses, even if he does not carry them out himself; and he must be to some extent a biologist, acquainted with the significance of bacteriology and the laws which govern the causation of disease.

For graduate students unusual facilities for advanced study are

offered by the Sanitary Research Laboratory and Sewage Experiment Station founded in connection with the Biological Department by an anonymous friend of the Institute. This Station furnishes an opportunity for investigating the problems of sewage purification such as probably no educational institution in the world can parallel. The treatment of the sewage of Boston is here being studied as it would be studied on a practical scale; and septic tanks, sand beds, contact beds, and trickling filters are available for special investigations. The Experiment Station has already attracted graduate students from various parts of the country, and has reacted upon the general instruction of the department in a most helpful way. Interesting results upon the treatment of industrial wastes have been obtained by members of the Station staff, working in coöperation with the United States Geological Survey, and important extensions of its work are contemplated in the future.

With regard to the third sanitary expert, the physician in public health work, the Institute has also something to offer. The courses in biology and engineering at Technology are specialized directly along sanitary lines, but not one of our medical schools has yet made a definite attempt to educate medical men to serve as experts in sanitation. The ordinary physician is no better fitted for his side of public health work than the ordinary civil engineer or the ordinary systematic biologist would be for theirs. There is great need of medical experts trained in sanitary science; and to meet this need the Biological Department of the Institute is prepared to offer a two years' course to graduates of ordinary medical schools, which will adequately fit them for positions as health officials for city or state.

In all these directions there is need for men of the right sort, energetic, patient, open-minded, and well trained. From the professions, already well developed, of sanitary bacteriology and sanitary chemistry and sanitary engineering calls are constantly coming which cannot be met for lack of men. Some conception of the need may be gained by recalling the demands which have already been made upon Technology men for work along these lines. With the Massachusetts State Board of Health there are at this writing twelve Institute men — five engineers, including the first and second assistant engineers; five chemists, including the chief chemist, the first assistant chemist, and the chief analyst of food and drugs; and two biologists, including the biologist of the Lawrence Experiment Station. In Ohio the engineer-

ing department of the State Board of Health is entirely recruited from Technology graduates, including the chief engineer and four assistants. The State Boards of Health of New York and Minnesota have appointed Institute graduates as their chief engineers within the past three months. The chief engineer of the State Water Supply Commission of Pennsylvania and his first assistant are Technology men. To New Jersey we have sent the assistant chemist of the State Sewage Commission, to Maryland the chemist and bacteriologist of the Baltimore Sewage Commission, and to Louisiana the chemist and bacteriologist of the New Orleans Water and Sewerage Board. Vermont has one of our men as chemist, Rhode Island one as assistant chemist, and to Connecticut and Iowa we have sent assistant bacteriologists. The national government, through the United States Geological Survey, is making extensive studies of water supply and stream pollution problems, which fall into direct line with these state and municipal investigations; they are being carried out by one of our graduates as chief hydrographer, while half a dozen others are employed as his assistants.

In the municipal field, we have furnished Richmond, Virginia, Plainfield, New Jersey, Montclair, New Jersey, and Elizabeth, New Jersey, with health officers. The city bacteriologist of the city of Boston and the director of the Water Supply Laboratory of the city of New York, with several of his assistants, are Institute men. The epidemiological studies at Waterville, Maine, Washington, District of Columbia, and Cleveland, Ohio, the investigations on the Chicago Drainage Canal, the experiments on water purification at Louisville, Kentucky, Cincinnati, Ohio, New Orleans, Louisiana, and Pittsburg, Pennsylvania, have been carried out under the direction of Technology graduates. The construction of the filter plants at Albany, New York, Harrisburg, Pennsylvania, Watertown, New York, Little Falls, New Jersey, New Milford, New Jersey, Springfield, Massachusetts, and many others was in the hands of Institute engineers; and Institute engineers and bacteriologists are at present in charge of the operation of the plants at Watertown, New York, New Milford, New Jersey, Little Falls, New Jersey, Springfield, Massachusetts, Birmingham, Alabama, Washington, District of Columbia, Columbia, South Carolina, Charleston, South Carolina, Knoxville, Tennessee, and Superior, Wisconsin. The construction of the new disposal work at Columbus, Ohio, is being carried out with a Technology engineer in charge, and four Institute men among the engineering assistants.

All this is only a beginning, for the work which remains to be done in the United States is still enormous. In the five years, 1898–1903, there were 126 cities with populations over 30,000. Eighty-two of them had average typhoid death rates of more than twenty-five per 100,000 population. Such death rates are due in almost every case to the use of polluted water, and in every case to some gross sanitary neglect. As epidemics occur or as the public conscience is awakened these water supplies must be purified. In 1902 Mr. G. W. Fuller estimated that among the cities and towns with a population over 3,000 there were 1,100 sewerage systems and only ninety disposal plants. It is very probable that the next two decades will see a large proportion of the thousand systems, which now discharge untreated sewage, equipped with modern disposal plants. The systems of state supervision of water supply and sewage disposal now in force in Massachusetts and Ohio and New Jersey and Pennsylvania are certain to be extended to the other progressive states of the Union.

This is the field for the Institute's graduates in sanitary science. The Biological Department continues to offer a fundamental scientific training to those entering upon the study and practice of medicine It prepares men and women for the teaching of natural science in the school, the high school, and the college. It furnishes specialists in the increasing applications of biology to the development of the arts and industries. Its chief function, however, is to train recruits for the new crusade against disease; and this function is limited only by the number of volunteers and by the facilities necessary for their equipment.

BOOK REVIEWS

Street Railway Investments[1]

Each year adds something to the completeness of this work as a guide to investors in street railway securities. The alphabetical arrangement by states and towns within each state makes it easy to compare adjacent properties, and the placing of each interurban road under the largest city on its line renders the full index at the back of the book almost unnecessary. The work includes all the street railways of the United States, the insular possessions, Cuba, and Canada. The essential facts in regard to each railway are given, and in the case of the older and larger roads fairly complete financial and operating statistics covering a period of years are compiled. The work also includes forty-nine maps, showing the systems of fifty-two separate companies, mostly interurban.

The book probably meets the needs of those for whom it is prepared, but one cannot help regretting the lack of general tables of statistics, such as are given in Poor's Manual and in the reports of the Interstate Commerce Commission. It is perfectly evident from a glance at the several volumes of this work that there has been a rapid growth in street railway mileage and in the consolidation of systems during recent years, but one would like to see this growth more definitely measured. This growth is shown in a way, however, by some general tables of gross receipts. For example, in 1902 there were thirty-eight companies whose gross receipts exceeded $1,000,000 each, with a total of $159,336,273. In 1905 there were fifty-one such companies, with a total gross income of $227,946,916. The growth in number of companies having gross incomes of from $100,000 to $1,000,000 was still more marked. There were 107 such companies in 1902 and 209 in 1905, and the gross earnings of this class had increased from $32,201,783 to $64,706,527 during the three years. Without doubt a considerable

[1] American Street Railway Investments. Supplement to the Street Railway Journal. New York: McGraw Publishing Co., 1906. 13, 38 + 432 pp., fol.

part of this increase was due to the consolidation of previously existing small roads; but the fact that the number of small roads has increased at the same time, though not so rapidly, indicates a remarkable growth in new enterprises. Another striking aspect of this growth in railway systems is noted when one looks over the list of states. Wyoming among all of the states and territories is the only one which has no street railways. All this is, of course, simply another indication of the wonderful progress and prosperity of the country.

If one were to criticise this work, it would be along the line of statistics of physical plant, and this would be really a criticism of the roads themselves because of the incompleteness of their reports at this point. In many cases financial and operating statistics are given for a number of years, while there is nothing to indicate additions to equipment or increase in mileage during the same period. The reports would be much more useful to the investor if these figures were included. It is evident, however, that promoters and directors of street railways as well as other corporations are coming to realize the necessity of making more adequate reports, and it is probable that future volumes of this work will afford still more complete and satisfactory data than the one under review. C. W. D.

The Steam Turbine

In a new work entitled, "Steam Turbine Engineering,"[1] this modern form of engine is treated from the standpoint of one interested in the commercial side of power generation. Short chapters are given to descriptions of the mechanical features of well-known turbines, but the major portion of the book is devoted to comparative studies of economy, size, cost, and conditions of operation of turbines and auxiliary machinery now in use in many parts of the world.

During the rapid development of the turbine since 1900, the principles involved in new constructions, together with approximate details of improved designs, have generally been published soon after the patents were granted; but authentic data as to cost, and reliable figures showing the steam and heat economy, have, for obvious reasons,

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[1] Steam Turbine Engineering. By T. Stevens and H. M. Hobart. New York: Macmillan, 1906. 814 pp., 516 il.

usually been withheld. Such information, nevertheless, has gradually accumulated and is now available in the recent technical magazines and transactions of engineering societies. Messrs. Stevens and Hobart have accomplished the difficult task of collecting, systematizing, and comparing most of this data, adding thereto a good deal of valuable information secured directly from turbine manufacturers.

Although written for English-speaking engineers, the tabular portion of this book is nearly all in the metric system, with pressures expressed in kilograms per square centimeter and temperatures in Centigrade. English units also are given in many cases. For tests where the turbine output was measured by means of a dynamo the observed results are quoted; where it was measured by other means a dynamo was assumed, having a *standard efficiency* determined after investigating very many generators of types suited to turbine requirements. Thus the output for all tests is reduced to kilowatts, and the economy is, therefore, easily compared.

Chapters XV and XVI are particularly interesting, dealing with performances of reciprocating engines built since 1899 and comparing them with average results for turbines, showing the effect of variation in load, pressure, vacuum, and superheat.

Conditions of operation, with data concerning the buildings, boilers, turbines, condensers, and pumps for a large number of reciprocating and turbine plants, are given in Chapters XVII to XXI. Chapter XXII presents, in tabular form, a digest of more or less important data from twelve large electric generating stations, where steam turbines furnish all the motive power. Eighty different items are listed, including not only the turbines and auxiliaries, with special features of the generators and electrical equipment peculiar to turbine stations, but also a mass of data concerning the boiler plants and coal-handling apparatus. Each station is fully illustrated with photographs showing arrangement of buildings and machinery. Chapters XVII to XXII alone would make a very acceptable book on steam turbine practice.

More than a hundred pages are devoted to the marine steam turbine, but here the matter and illustrations are nearly all taken from previous publications, with little that is really new and considerable that is obsolete. The data tables in this chapter are left blank in many places where the desired information could easily have been obtained.

Examination of the voluminous bibliography of turbine literature

since 1896, given in the last chapter, will convince one of the value of this book in collecting under one set of covers a summary of the information previously scattered through so many different journals, many of which are not accessible to the average reader.

J. C. Riley.

Food Materials and Their Adulterations[1]

On account of the present general interest in all things pertaining to the propaganda of "pure food" the appearance of a revised edition of this book is particularly timely. As the author very truly says in the preface to this edition, "Conditions have changed with marvelous rapidity in the twenty years since this little book was written, and in no quarter more than in the food problem."

This is well shown by the changes made necessary in the treatment of some of the subjects discussed. The question of coffee substitutes, for example, is not mentioned in the earlier edition, these benefactors of mankind having been introduced since that time. Analyses made at some of the State Experiment Stations are quoted which show up clearly the ridiculous claims to "high nutritive value" put forward in behalf of some of these preparations. In the discussion of cereals and cereal foods the modern breakfast foods are much more in evidence than formerly. In the early edition the question of the wholesomeness of "tinned foods" was devoted for the most part to the danger from solution of the tin and consequent harm; the question is now largely one of artificial coloring, addition of chemical preservatives, and the imposition upon the consumer by the substitution of cheaper and less wholesome ingredients.

Two points made by the author are worthy of special commendation: the suggestion in regard to the establishment of a "high school museum" for exhibiting conditions as regards local goods, and the stress laid upon the need for cleanliness in handling, preparing, and exhibiting food, lack of which is a source of danger far greater than adulteration with cheap but wholesome substitutes.

Some of the tests for the purity of sugar given in the earlier edition

[1] Food Materials and Their Adulterations. By Ellen H. Richards. Third edition, revised and rewritten. Boston: Whitcomb & Barrows, 1906.

are omitted, which is just as well. The case against sirups is made to appear rather blacker than is warranted, the high percentage of adulteration being largely because the manufacturers have had free rein in the past, satisfactory methods for the detection of adulteration of maple sirup being very recent. It is not always made sufficiently clear that the analyses referred to and the ratio of adulteration found are those of twenty-five years ago.

The adulteration of spices is not now so much a matter of the addition of foreign material, to be detected by the microscope, as of the blending with cheaper grades, shown only by careful chemical examination.

It might be mentioned in passing that the simple test described on page 153 for the detection of alum in baking powders is not a general one, and a negative result is not evidence that alum is absent.

The general appearance of the book is a considerable improvement over that of the earlier one, but the list of references shows lack of care on the part of either compiler or proof-reader.

A. G. Woodman.

A Text-Book of Sanitary Chemistry[1]

A résumé of the chapter headings will indicate the wide scope of this book of 325 pages: The Atmosphere; Fuels; Heating and Ventilation; Lighting; Water; Purification of Water Supplies; Disposal of Household Wastes and Garbage; Use of Soap and Bluing; Disinfectants, Antiseptics, and Deodorants; Food; Cellulose, Starch, Dextrine, Legumes; Bread; Breakfast Foods and Other Special Foods; Sugars; Glucose; Leaves, Stalks, Roots, etc., Used as Food; Composition and Food Value of Fruits; Edible Oils and Fats — Food Value of Nuts; Meat; Eggs; Milk, Cheese, and Butter; Non-Alcoholic Beverages; Alcoholic Beverages; Food Accessories; Preservation of Foods — Coloring of Food Products; Economy in the Preparation and Selection of Food — Dietaries.

Under each heading a very considerable mass of information is given, which makes the book a desirable one for the general reader

[1] A Text-Book of Sanitary and Applied Chemistry, or The Chemistry of Water, Air, and Food. By E. H. S. Bailey. New York: Macmillan, 1906.

as well as for the student. For class work numerous well-chosen illustrative experiments are given.

Both this and Mrs. Richards's book, reviewed above, should be on the shelves of every high school and college library.

The author states well in the closing paragraph of the Introduction the basic purpose for which the book was written: "A thorough understanding of the facts of applied chemistry will not make the skilled workman, nor will the theories of chemistry make the accomplished cook; but a broad and thorough knowledge of the underlying principles will go very far toward developing common sense in hygiene and in the selection and preparation of food." A. G. WOODMAN.

PRODUCER GAS[1]

THIS little book gives a list of 287 questions on the fundamental definitions involved in producer-gas manufacture, upon its history and status, its uses and cleaning, and upon the construction and handling of gas producers.

The material is well chosen and the explanations clear and concise, so that any one after its perusal should have a good understanding of the subject.

The only feature open to unfavorable criticism is the relatively high cost of the book, it being about double the usual price of scientific books, and this in view "of the limited literature on the subject that has been available in the past" (answer to question No. 190).

A. H. GILL.

A FIVE-FIGURE TABLE OF LOGARITHMS[2]

THIS is a small book, convenient to carry in the pocket, and contains nineteen pages of text, beginning with a section in which the theory

[1] Catechism on Producer Gas. By Samuel S. Wyer. New York: McGraw Publishing Co. 42 pp. $1.00 net.

[2] Five-Figure Logarithms of Numbers and Angular Functions for the Use of the Engineer, Constructor, and Student. By H. H. Suplee. Philadelphia: Lippincott, 1906. 91 pp., 16mo. $2.00.

of logarithms is explained very simply and clearly. Then follows a description of the tables of logarithms, with directions for obtaining the logarithm from a number and the number from the logarithm, with interpolation by the usual method. A separate section is devoted to the logarithms of fractions, with directions for decimal points, and the like. These sections are followed by others giving numerical examples of the use of logarithms for various purposes. The table of logarithms of numbers gives the logarithms to five places for the numbers from 1 to 1,199. It is clearly printed and well spaced, and has marginal tables of proportional parts. This is followed by the table of the logarithmic angular functions from 0° to 180°. The book ends with the table of hyperbolic logarithms to seven places for the numbers from 1.01 to 134.

This book undoubtedly will prove useful for ordinary calculations. The clearness of the type and the small size and lightness of the volume make it very convenient. It is a pity, however, that the binder did not put the book together in such a way that it will lie open easily. And the book would have been better if the table of logarithms of numbers had been arranged so that the change in the first place of the number should always come at the top of the left-hand page. This would require the addition of only an inch and a quarter to the length of the book, and would have the further advantage of permitting leads to be used in the tables of angular functions and hyperbolic logarithms, thus giving a better spacing between the lines.

In the arrangement of the vertical columns of the table of logarithms of numbers the Germans generally employ a greater number of ruled lines to guide the eye from the numbers at the top of the column to the logarithms below. For example, in "Erdmann und Kötner, Naturkonstanten" (Berlin, Springer, 1905), we find a ruled line between the column headed 0 and 1, between 3 and 4, and between 6 and 7. This divides the table into one column for the whole number on the left and into three blocks of three columns each for the significant figures of the fourth place. This has been found in practice by the reviewer to be an improvement over the traditional English and American fashion, followed in this volume, of dividing the table by a single ruled line between the columns headed by 4 and 5.

American and German Education Compared[1]

This little book is a critical comparison of the conditions in American and German universities and schools for higher education, and is written especially with the aim of presenting to German readers that which is of merit in American institutions. The author's experience was gained by one year's residence in America, during which time he occupied the station of research associate at the Massachusetts Institute of Technology. By nature and training a keen observer and student of conditions, he has gained a remarkably thorough appreciation of the methods and the ideals of American higher education as typified in the Massachusetts Institute of Technology and Harvard University. As he himself emphasizes, he has not immediately embodied his ideas in print, but has first allowed them to mature during several months after his return to his work in his native country. He thus can give a fairer survey of the subject, and not one distorted by the accidental being mistaken for the typical, as has been done by some who have essayed to express themselves upon this subject.

America is, according to Dr. Böttger, the land of experimentation in educational matters. It is only during the last thirty years that the American universities have developed to their present importance. Their life is, therefore, younger and thus more energetic.

The length of time occupied in the preparatory schools by the youth of both countries is about equal — an average of twelve years; yet the graduate of the American preparatory school has only the training requisite for entrance to the highest class of the German "gymnasium." The reason for this is, naturally, that the American boy is not so severely pressed in his studies, whereby more opportunity is given for his very essential physical development.

The first years of the American college are still in the nature of preparation for his special line of study; thus the transition from a condition of dependence in the preparatory school to one of independence in the higher school is a gradual one. Much stress is laid by the author upon the American system of supervision of the student's work, as compared with the German system of complete freedom. The advantages of the American method are evident: that many students are guarded against mistakes which would entail serious consequences.

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[1] Amerikanisches Hochschulwesen, Eindrücke und Betrachtungen. By Dr. W. Böttger, Privatdozent at the University of Leipsic Leipsic: Wilhelm Engelmann, 1906. 70 pp.

Contrasted to this, the German system suddenly throws the student wholly upon his own responsibility; upon entrance into the university his choice of studies is unrestricted, and he takes no examination until his final one, when he deems himself prepared to try for the degree of "doctor" from the university. The German contends that his system possesses the advantage that those who do not make the proper use of the freedom accorded to them will sooner or later fall out, so that only those will reach the goal who properly understand the privileges and duties of the student's freedom. This argument, however, presupposes that the student already has that which he must first acquire. In America the same goal is striven for, but with fewer losses, in that the transition to the condition of independence is made gradual.

The difference in the ideals of education in the two countries may be summed up in the following: In America the aim of the higher education is to increase the efficiency of the average man, while in Germany the stress is laid upon bringing the best to the highest development. The author seems to reach the conclusion that due precaution is exercised in America to prevent the invasion of the less diligent into the ranks of the learned professions, while, at the same time, pains are taken to develop the less gifted, who are on this account the more in need of education.

The author discusses at some length the matters of state and private schools, the organization of instruction, the cost of instruction and scholarships, athletics, and the love and loyalty of the alumni of a school for their Alma Mater. As evidence of the last mentioned point, he cites the active part taken by the alumni of the Massachusetts Institute of Technology in the discussion of the plan for the merger of that school with Harvard University. Indeed, he ventures the opinion that the final miscarriage of that plan was to be attributed, at least in part, to the vigorous opposition on the part of the alumni.

Many matters of interest are treated which cannot be touched upon in this review. The author has dealt very lightly with our failings and has devoted himself chiefly to pointing out to his countrymen, with whom education is an established science, that which has been attained in a country where education is still in the state of development. It is a matter of interest to learn those points in our system which are deemed commendable, or worthy of study, by a student trained in the Old World educational ideals. This work is of additional interest as treating the subject especially from the viewpoint of education in the

exact natural sciences, previous writers, in the main, having treated the subject in its relation to general culture.

ARTHUR A. BLANCHARD.

THE POLARIZING MICROSCOPE[1]

THIS book of only 147 pages is a noteworthy and commendable example of how concise and yet clear a treatise on a complicated and abstruse branch of applied optics can be made when the writer is master of his subject. While Professor Weinschenk ostensibly writes for the petrographist, there is much which is in touch with the work of microscopists generally, and with that of chemists who have learned the value of micro-chemical analysis.

Dr. Weinschenk himself states in his preface that he seeks to meet the need of the "non-specialist"; to give a book which, while brief, will make the fundamental principles of micro-crystallography intelligible to beginners, and be a guide to the practical use of the polarizing microscope rather than a reference work for experts. Certainly the author seems to have succeeded remarkably well.

The six chapters cover the following subjects: Fundamental optical principles of the microscope and polariscope, very briefly given; description of apparatus. Testing and adjusting of the polarizing microscope. Observations made with ordinary light, such as simple methods for determining index of refraction; and the bearing of refraction on the interpretation of images in the microscope; determination of cleavage, size, thickness; color classification and use of reflected light. Use of parallel polarized rays to show double refraction, and its bearing on the number and position of crystal axes, as shown by pleochromatic effects with a single nicol. Determination of planes of polarization by use of two nicols; the stauroscope; interference effects and their use in measuring double refraction; use of "compensators." Observations with converging polarized rays and discussion of methods of making such observations; optical effects given by crystals of different systems in converging light; circular polarization; determination of the angular position of crystal axes; twin and other anomalous crystals.

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[1] Anleitung zum Gebrauche des Polarisationsmikroskops. By Dr. Ernst Weinschenk. Second edition. Freiburg im Br.: Herder, 1906.

In an appendix there are descriptions of various accessory apparatus, among which are heating appliances for observations at high temperature, projection apparatus, and a convenient and very simple type of photo-micrographic camera. Finally, there is a tabulation and summary of the methods given, a set of simple rules for distinguishing the different crystal systems by their optical behavior, and a very full index.

The illustrations, which are numerous and excellent, greatly aid the text. The typography is of that high class characteristic of the best German bookmaking. G. W. ROLFE.

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